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AN EXPLORATORY ANALYSIS OF ECONOMIC FACTORS IN THE NAVY TOTAL FORCE STRENGTH MODEL (NTFSM)

by

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December 2015

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Accurate forecasts of U.S. Navy enlisted end-strength are crucial for budgetary planning and the development of manpower policies. An improving economy and increased employment opportunities in the civilian sector could cause a significant problem for enlisted retention. The Navy Total Force Strength Model (NTFSM) is a new stochastic simulation that is intended to offer manpower analysts more accurate enlisted manpower projections than those projected with the current tool. NTFSM uses historical data and user-defined inputs for economic factors to project monthly retention losses. However, NTFSM is still in the testing phase and its overall behavior is largely unknown. In particular, the analysts that NTFSM was designed to help are unsure of the effects that the economic factors, which they need to enter themselves, have on NTFSM's output. This thesis investigates the behavior of NTFSM's output and the sensitivity of the user-entered economic factors. Using design of experiments and data mining, a variety of scenarios are simulated and then analyzed to better understand the behavior of the model and to determine the sensitivity of the user-defined economic factors. The results of the analysis unexpectedly show that NTFSM's economic factors have no significant impact on NTFSM's end-strength output; this warrants further investigation.

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TOTAL FORCE STRENGTH MODEL (NTFSM)**

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ABSTRACT

Accurate forecasts of U.S. Navy enlisted end-strength are crucial for budgetary planning and the development of manpower policies. An improving economy and increased employment opportunities in the civilian sector could cause a significant problem for enlisted retention. The Navy Total Force Strength Model (NTFSM) is a new stochastic simulation that is intended to offer manpower analysts more accurate enlisted manpower projections than those projected with the current tool. NTFSM uses historical data and user-defined inputs for economic factors to project monthly retention losses. However, NTFSM is still in the testing phase and its overall behavior is largely unknown. In particular, the analysts that NTFSM was designed to help are unsure of the effects that the economic factors, which they need to enter themselves, have on NTFSM's output. This thesis investigates the behavior of NTFSM's output and the sensitivity of the user-entered economic factors. Using design of experiments and data mining, a variety of scenarios are simulated and then analyzed to better understand the behavior of the model and to determine the sensitivity of the user-defined economic factors. The results of the analysis unexpectedly show that NTFSM's economic factors have no significant impact on NTFSM's end-strength output; this warrants further investigation.

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TABLE OF CONTENTS

viii

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LIST OF FIGURES

LIST OF TABLES

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LIST OF ACRONYMS AND ABBREVIATIONS

APEX   Oracle Application Express
DOD   Department of Defense
DOE   Design of Experiments
DON   Department of the Navy
EAOS   Expiration of Active Obligated Service
FY   Fiscal Year
GUI   Graphical User Interface
MPT&E   Manpower Personnel Training & Education
NESP   Navy Enlisted Strength Planning
NOLH   Nearly Orthogonal Latin Hypercube
NMPBS   Navy Manpower Program and Budget System
NTFSM   Navy Total Force Strength Model
OCS   Officer Candidate School
OPNAV   Office of the Chief of Naval Operations
OSAM   Officer Strategic Analysis Model
PII   Personally Identifiable Information
POM   Program Objective Memorandum
SEED   Simulation Experiments & Efficient Design

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EXECUTIVE SUMMARY

The Navy's current manpower and personnel forecasting tool was developed nearly 20 years ago and, with the changing budget and retention environment, can no longer keep up with the demands of modern Navy manpower and personnel analysis. The Navy Total Force Strength Model (NTFSM) is poised to replace the current tool; however, it is still in its testing phase. NTFSM is an agent-based, stochastic simulation that incorporates historical data and user-defined economic factors to project enlisted personnel losses and gains into the future. NTFSM has undergone initial verification testing, but much is unknown about the model and how it behaves. This study serves as an initial exploration and analysis of the behavior of NTFSM scenarios under differing economic environments and also as a proof of concept for simulation analysis and meta-modeling techniques. The results demonstrate the sensitivity of NTFSM outputs to changes in the user-defined economic factors. This information can be used to help manpower and personnel analysts better understand NTFSM's strengths and weaknesses—and eventually lead to better utilization of NTFSM's capabilities.

NTFSM currently resides on a Navy Manpower Program and Budget System (NMPBS) testing server and can be accessed through the Navy Total Force Strength Management System Graphical User Interface (GUI). The GUI allows for the user to create unique NTFSM scenarios and access NTFSM output reports which can then be analyzed.

With support from the Simulation Experiments and Efficient Designs (SEED) Center, an efficient Nearly Orthogonal Latin Hypercube (NOLH) Design of Experiments (DOE) is utilized to generate NTFSM output data that covers a wide spectrum of economic possibilities. The NOLH design used varies economic factors to efficiently achieve maximum coverage of the range of possible values. The experiment in this study utilizes fiscal year 2014 data to project one fiscal year into the future (FY2015). However, due to limited

computing resources available on the NMPBS testing server on which NTFSM is currently housed, of NTFSM's 12 economic factors, only seven were explored in this thesis. In addition, of the numerous outputs NTFSM produces, only sensitivities of the main outputs which pertain to End Strength were explored.

Analysis and meta-modeling of the data generated by the DOE show that, when using FY2014 data to project one year into the future (FY2015), at least some stochastic variation is present in all of NTFSM's main outputs and most are approximately normally distributed. The End Strength output is the only NTFSM output which is not normally distributed and does not conform to any of the common statistical distributions. The End Strength output also experiences nearly no stochastic variability, with an estimated mean of approximately 265,777 and a standard deviation of only 3.85; this result warrants further investigation. Table 1 shows which of NTFSM's economic factors have an effect on the main NTFSM outputs explored.

Table 1.   Summary of NTFSM Economic Coefficients that Have an Effect on the NTFSM Outputs Explored

	Reenlistment		Recruit Losses		Attrition Losses		Long Extensions
	Unemployment	Pay	Unemployment	Pay	Unemployment	Pay	Unemployment
Attrition Losses	NO	NO	NO	NO	YES	YES	NO
Retirement Losses	NO	NO	NO	NO	YES	NO	NO
Recruit Losses	YES	NO	NO	NO	YES	NO	YES
EAOS Losses	YES	NO	NO	NO	NO	NO	YES
Prior Service Gains	NO	NO	NO	YES	YES	YES	YES
Recruit Gains	YES	NO	NO	NO	YES	NO	NO
End Strength	NO	YES	NO	YES	YES	NO	YES

This thesis was constrained in scope by the available computing resources on the NMPBS testing server on which NTFSM is currently housed. To improve upon this limitation, this author has been working with the SEED Center to develop a method for transferring the NTFSM simulation and historical data repository to the SEED Center high-speed cluster computing server. High-speed cluster computing opens up the possibility for further exploration of all 12 of NTFSM's economic factors (as well as many additional factors), thus enabling the ability to produce more generalized results.

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I. INTRODUCTION

The Navy had an estimated end-strength of approximately 323,600 (53,400 officers and 270,200 enlisted personnel) in fiscal year 2014, at a cost of approximately $45.4 billion out of a total budget of $155.8 billion (Department of the Navy, 2013). Navy enlisted personnel planning is a difficult and complex process. To help advise senior leadership on personnel matters, manpower analysts at the Office of the Chief of Naval Operations (OPNAV) Manpower, Personnel Training, & Education (MPT&E) Resource Management Division, Strategic Resourcing Branch (N100) use a deterministic forecasting tool called the Navy Enlisted Strength Planning (NESP) model. NESP takes the population of Enlisted Sailors who are eligible to leave the Navy in a given year and applies percentages based on historical data to categorize and quantify expected retention losses. Realistically, however, the model is not used for forecasting, as loss percentages are calculated outside of the model and the model is only used to help determine the number of losses by paygrade and to output the results in the format that the Manpower Budgeting Office (PERS-7) requires.

In hopes of stemming the growing proportion of resources consumed by personnel costs, the Department of the Navy (DON) has put an emphasis on efficient manpower management by implementing new talent management initiatives (Department of the Navy, 2015). NESP does not have the ability to give much insight into how future policy changes or economic factors might affect retention, losses, and gains; this leaves the manpower analysts at N100 unable to efficiently quantify many of the effects that any economic or policy changes may have on future personnel budget demands.

The margin of error that N100 has to operate in is very small. The required accuracy of manpower forecasts is set by congress. By law, the Navy's total number of active duty personnel at the end of the fiscal year must conform to the end-strength guidelines set by Congress to within three percent above or .5 percent below authorized end-strength (Title 10 United States Code). The Navy

realizes that a more robust manpower and personnel planning tool is needed in order to gain the insight required to better manage the enlisted force and has begun developing a new manpower personnel model called the Navy Total Force Strength Management (NTFSM) model. NTFSM is an agent-based stochastic manpower simulation that uses real historical data pulled from Navy Manpower Program and Budget System (NMPBS) databases. In addition to using historical data, NTFSM allows its users to input economic factors and policy effects. Although NTFSM has made it through its first round of the validation process, it is still in the testing phase and very little is known about the model's behavior or the sensitivity of its output to changes in the user-defined economic factors (S. Cylke, personal communication, March 25, 2015).

A. PROBLEM STATEMENT AND PURPOSE

Before NTFSM is ready to replace NESP as N100's main manpower and personnel forecasting tool, more needs to be known about the behavior of NTFSM's output. NTSFM relies on a "seeded" random number generator and, like most stochastic simulations that do so, its results *should* be repeatable if the same seed is used. There has been no research, however, into NTFSM's ability to produce repeatable results so it is uncertain if NTFSM possesses this capability. This is a big concern for N100 since the manpower and personnel forecasts and analyses that they generate are used by top-level decision makers when considering changes to Navy-wide manpower and personnel policies, and therefore must be able to stand up to extreme scrutiny. It is extremely important to ensure that NTFSM's output is repeatable before NTFSM can leave the testing phase.

Additionally, no research has been done on the sensitivity of NTFSM's main simulation outputs to changes in its user-defined economic inputs. As it stands now, it is unknown which economic inputs affect, and to what degree they affect, the model's outputs. Since NTFSM is a stochastic simulation it is important to run several iterations of the simulation in order to gain insight on the

distribution of possible results. A large number of runs for a single simulation scenario has never been attempted on NTFSM and therefore the variability of the model's output is largely unknown.

This thesis uses a quantitative approach to better understand the strengths and weaknesses associated with using NTFSM for manpower and personnel forecasting. This is done using the current graphical user interface (GUI) as it appears on the NMPBS test server. A robust and efficient experimental design is developed to help better understand the limits of the model. The results of the design are analyzed using advanced statistical and simulation analysis techniques to help indicate which of the user-defined economic factors tested have the greatest impact on the model's main outputs and to gain a better understanding of the these outputs' behaviors.

B.   RESEARCH QUESTIONS, METHODOLOGY, AND BENEFITS

This research conducts a broad exploratory analysis into the behavior of NTFSM under a variety of economic scenarios, by using an efficient experimental design, to gain valuable insight into the model's general behavior and to help better quantify its strengths and limitations. The following questions guide the experimental design and the analysis of the collected data.

1.   Are the results generated by NTFSM repeatable?

2.   What is the general behavior of NTFSM's main outputs?

3.   How sensitive are NTFSM's main outputs to changes in its user-defined economic factors?

This research utilizes advanced design of experiment (DOE) techniques developed by the Simulation Experiments & Efficient Designs (SEED) Center, an organization within the Naval Postgraduate School that promotes research and advancement of simulation analysis, particularly for defense applications.[1] The user-defined economic factors that have the greatest potential for volatility needed to be initially identified. With some guidance from N100's manpower and

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[1] For more information, visit the SEED website at https://harvest.nps.edu.

personnel analysts, the user-defined economic factors chosen to be varied are those pertaining to Expiration of Active Obligated Service (EAOS) losses, Recruit gains, Reenlistments, Long extensions, and Attritions. All other factors are kept at their default values. Once the design is run and the output data collected, advanced statistical methods and metamodeling techniques are used to explore relationships between input factors and model output to develop an understanding of the response surfaces and answer the research questions.

NTFSM provides a promising new tool that can be used to gain novel insights into manpower and personnel forecasting. These insights have the potential to provide valuable information to top-level Navy decision makers. The insights into the behavior of NTFSM that this study provides helps quantify the behavior of the model and gives N100's manpower and personnel analysts a better overall understanding of the strengths and limitations of the model, which will, in turn, allow them to conduct more meaningful analysis of the model's output.

C.   LITERATURE REVIEW

This study focuses on the use of design of experiments to gain insight into how user-defined economic factors affect the behavior of NTFSM's output. Many studies have been conducted that focus on the effect of economic factors on manpower and retention, such as in Pinelis and Huff (2014). Designs of experiments have been used in academic theses, including Erdman (2010) and DeHollan (2015), to efficiently explore the behavior of other similar manpower models, such as the Army's Enlisted Specialty model and the Navy's Officer Strategic Analysis Model (OSAM). A brief review of some of these studies follows.

1. Economic Factors and Retention

A recent Center for Naval Analysis study focuses on the relationship between the economy and the decision an enlisted Sailor makes on reenlistment using data from 1992 to 2012 (Pinelis & Huff, 2014). The study found that economic factors could affect average retention percentages. For zone A personnel (personnel with less than six years of active service), this could be as much as a 25.1 percentage point increase during a time when the economy is weak; or, a decrease in average retention percentages for zone A personnel by as much as –21.8 percentage points during a time when the economy is strong (Pinelis & Huff, 2014). This, of course, represents only the most extreme economic scenarios, but it can serve as a basis for the constraining bounds of an efficient design of experiments.

2. Design of Experiments

Erdman (2010) uses design of experiments to explore the optimization component of the U.S. Army's Enlisted Specialty model, which is an enlisted manpower model that is used to minimize the deviation between Soldiers on hand and authorized positions available over a seven-year planning horizon. The model takes into account 859,633 variables and calculates projections against 224,473 constraints. Using design of experiments, Erdman was able to evaluate objective function coefficients that place weights on decision variables. The results of the study led to an average drop in misaligned Soldiers of 8,355 (equivalent to two combat brigades) a month for the seven year planning horizon (Erdman, 2010).

DeHollan (2015) applies design of experiments and data farming techniques to OSAM in order to explore the effect of economic factors on un-restricted line officer end-strength. Factors with the greatest potential for affecting end-strength were identified and varied in the experiment. The resulting output data was farmed and statistical methods were used to explore relationships between factors. Metamodeling was used to build a comprehensive

understanding of retention issues. DeHollan (2015) and Erdman (2010) serve as a proof of concept that design of experiments that vary economic inputs can be used to gain insight into the output and overall behavior of manpower and personnel models.

II. NAVY TOTAL FORCE STRENGTH MANAGEMENT SYSTEM

This chapter gives an in depth overview of NTFSM, including additional information on NTFSM's development, verification and testing, and design. NTFSM is an agent-based stochastic model which utilizes historical manpower and personnel data that is accessed by the model directly through the Navy Manpower Program and Budget System (NMPBS). The model is currently housed on an NMPBS testing server, but it is intended to be moved to a NMPBS main server once it has completed its testing phase. Users access NTFSM through the Navy Total Force Strength Management System Graphical User Interface—where model scenarios can be designed, multiple simulations can be run, and reports can be generated. This study accessed NTFSM solely by utilizing the Navy Total Force Strength Management System Graphical User Interface and, because of limited computing capacity on the NMPBS testing server, this study was somewhat limited on the scope of possible simulation runs.

A. NTFSM DEVELOPMENT

Total force strength planning and execution is critical to OPNAV N1 Program Objective Memorandum (POM) analysis. The current strength model has been in use for approximately 15 years and has capability shortfalls. OPNAV N1 needs a more timely and accurate analysis of the total force and better connections to community-level models that will result in improvements in operational strength and readiness (Department of the Navy, 2011). Because of this, the Department of the Navy started developing a new manpower and personnel model. The Department of the Navy first officially began development of NTFSM in 2011, when the Navy Total Force Strength Model Program Plan gained final approval from N100, N816M, and N14 (the predecessor of the Strategic Actions Group). The purpose of the Navy Total Force Strength Model Program Plan was to define and guide project efforts to develop a new enlisted strength model that would assist in total force strength planning, analysis, and

execution. The Navy Total Force Strength Model Program Plan defined the project's scope, purpose, objectives, and capabilities, as well as the test, verification, and acceptance terms of NTFSM (Department of the Navy, 2011). In 2012, Serco, a DOD contracting agency was chosen as NTFSM's developer. Serco developed NTFSM using the Navy Total Force Strength Model Program Plan as guidance for the model's capabilities. A list of the required model capabilities as mandated by the Navy Total Force Strength Model Program Plan can be found in Appendix A.

B.   NTFSM VERIFICATION AND TESTING

The Navy Total Force Strength Model Program Plan mandates that a Testing and Verification Plan be developed for NTFSM; such a plan was drafted in June of 2013 and executed in January 2015. The results, published in Heider (2015), tested a total of eight requirement categories:

1.   Navy Total Force Strength Model Requirements

2.   Personnel Calculation Requirements

3.   End Strength Calculation Requirements

4.   Data Repository Requirements

5.   Econometric Calculation Requirements

6.   User Interface Requirements

7.   Strength Planning Requirements

8.   Analytical Capability Requirements

The Verification and Testing Results found that there were approximately 56 total requirements mandated by the Navy Total Force Strength Model Program Plan that were not met, and approximately 72 that were only partially met (Heider, 2015). Some of the unmet requirements not met that are relevant to this study include the requirement to verify that the model incorporates (in the personnel calculations) econometric effects to Losses by Expiration of Active Obligated Service, Attrition, and Length of Service (Heider, 2015). This

requirement was tested by injecting a 12 percent unemployment rate into a NTFSM scenario. It was found that there was no statistical difference between this scenario and a baseline scenario that used the default "null value" setting for the unemployment rate factor. A second simulation scenario was run which set the unemployment rate factor to 12 percent, and also set all other economic factors (referred to as "Economic Coefficients" in the Navy Total Force Strength Management System Graphical User Interface) to 1.0. It was found that the results of this scenario were statistically different from the baseline scenario. The results of this test led the tester to conclude that, because the user is forced to "guess" the extent to which NTFSM's economic coefficients impact the variables by manually entering values for these coefficients, the adherence to the requirement that NTFSM incorporates economic effects to losses is weak (Heider, 2015).

This author was not able to find any other information on the verification and testing process past the date of Heider (2015), but speculates that N1 is working with the developer to find solutions to NTFSM's deviations from the requirements mandated by the Navy Total Force Strength Model Program Plan.

C.   NTFSM SOFTWARE ARCHITECTURE AND ITS WEAKNESSES

The Navy Total Force Strength Management System is currently housed on an NMPBS test server, but is intended to be moved to a main NMPBS server once it has completed the verification and testing phase and is officially accepted by the Department of the Navy. The Navy Total Force Strength Management System's Graphical User Interface was developed using Oracle Application Express (also known as APEX). The historical manpower and personnel data repository utilized by the Navy Total Force Strength Management System is hosted using Oracle database software. The computational implementation of NTFSM's simulation is written in the Java programming language. The Oracle APEX and data repository architecture utilized by the Navy Total Force Strength Management System make it impossible to transfer NTFSM to a server that does

not have licensed Oracle and APEX software installed. If NTFSM were able to be more easily transferred to other servers then it would, in theory, be possible to utilize High Speed Multi Processor Cluster Computing Systems, such as the one housed at the Naval Postgraduate School's Simulation Experiments & Efficient Designs Center for Data Farming. Cluster computing could potentially allow for the analysis of the entire spectrum of NTFSM simulation output, providing invaluable insight into NTFSM's behavior, and giving analysts the ability to explore NTFSM's true potential as a forecasting tool.

D. NTFSM GRAPHICAL USER INTERFACE AND SCENARIO BUILDING

The Navy Total Force Management System is accessed through the NMPBS Portal. Users must first request an account to allow access to the NMPBS server before being able to log in via Common Access Card to the Navy Total Force Management System Graphical User Interface Home Page, which is shown in Figure 1.

Figure 1. Navy Total Force Strength Management System Graphical User Interface Home Screen

Source: Navy manpower programming and budget system. (n.d.). Accessed December 9, 2015. https://nmpbst1.n10.npc.navy.mil/pls/nmpbstst/f?p=221:1: 15989421618401

The Navy Total Force Strength Management System Graphical User Interface Home Screen serves as a starting point for accessing NTFSM and gives up-to-date information on the latest month and fiscal year of historical data available in the Navy Total Force Strength Management System's data

repository. Although the repository contains historical data for both Active Duty and Full-Time Support Enlisted Personnel, this study focuses on the Active Duty component of the data. Currently, the data repository contains historical manpower and personnel data for Active Duty Navy Enlisted Personnel starting from October of fiscal year 2005 to February of fiscal year 2015.

Users begin the scenario building process by accessing the Scenario Screen via the Scenario Tab on the Navy Total Force Strength Management System Graphical User Interface Home Screen. A snapshot of the Navy Total Force Strength Management Systems Graphical User Interface Scenario Screen is shown in Figure 2.

Figure 2.   Navy Total Force Strength Management System Graphical
User Interface Scenario Screen

Source: Navy manpower programming and budget system. (n.d.). Accessed December 9, 2015. https://nmpbst1.n10.npc.navy.mil/pls/nmpbstst/f?p=221:1: 15989421618401

From the Scenario Screen the user can compare the policies of two previously created scenarios of their choosing by using the "Compare" button located at the middle right side of the page.

Clicking the "Create" button located to the left of the "Compare" button opens the Scenario Creation Screen where, in order to create a new scenario, users must enter a scenario name, a scenario description, choose the population group (Active or Full Time Support), choose the scenario start month and fiscal year, and choose the length of the scenario (from one to 10 fiscal years). Privacy settings can also be set on this screen, but, after reviewing all available NTFSM documentation, to include Serco (2014), and after speaking to Ms. Elizabeth Heider, who performed the initial verification and testing on NTFSM and authored the NTFSM Verification and Testing Report, this author has not been able to determine how the privacy settings affect the scenario since the Navy Total Force Strength Management System Graphical User Interface does not allow users direct access to any Personally Identifiable Information (PII).

After creating a new scenario or selecting a scenario that has previously been created and saved, the Scenario Details Screen is displayed. The Scenario Details Screen allows for easy access to the scenario's Policy Screens and any report sets that have been previously generated. There are a total of nine Policy screens, one each for policies pertaining to Attrition, Economics, Prior Service Gains, Demotion, Exam Advancements, Retirements, Expiration of Active Obligated Service, Non-Prior Service gains, and Un-exam Related Advancements. Figure 3 shows a snapshot of the Scenario Details Screen.

Figure 3.   Navy Total Force Strength Management System Graphical
User Interface Scenario Details Screen

This study focuses on the user-defined economic factors that can be modified on the Economic Policy Screen; specifically, those that are referred to on the Graphical User Interface as "Coefficients." The model separates economic factors into two categories: "Conditions" and "Coefficients." There are four total economic conditions that the user can modify: unemployment, inflation, civilian wage growth, and military wage growth. Heider (2015), however, reports that changing the unemployment condition from its default "null" value to 12 percent has no effect on NTFSM's output. It is unknown how, or if, the other economic conditions have an effect on NTFSM's output. This thesis research leaves the analysis of NTFSM's economic conditions to a future study and focuses on the analysis of NTFSM's economic coefficients.

NTFSM's economic coefficients are comprised of six events: Reenlistments, Long Extensions, Prior Service Gains, Recruit Losses, Attrition Losses, and Retirement Losses.   Each of these six events has two coefficients associated with them, one coefficient for the National Unemployment Rate and

the other for the Pay Variable. This author was unable to find the definition of "Pay Variable" in any of the NTFSM documentation, but assumes that the Pay Variable refers to either the Military Pay Rate or the difference between civilian and military pay growth. In any case, according to Heider (2015) it is unknown how, or to what extent, the unemployment and pay variable coefficients effect NTFSM's output. What is known about the economic coefficients is that the amounts entered into the Graphical User Interface are converted to percentages before being used by the simulation (Serco, 2014). A snapshot of the Economic Policy Screen with example economic coefficients entered is shown in Figure 4.

Figure 4.   Navy Total Force Strength Management System Graphical
User Interface Economic Policy Screen

Source: Navy manpower programming and budget system. (n.d.). Accessed December 9, 2015. https://nmpbst1.n10.npc.navy.mil/pls/nmpbstst/f?p=221:1: 15989421618401

E.   NTFSM REPORTS

For each scenario that is simulated by NTFSM, there are approximately eight reports generated. They are labeled Advancement, BLUF, Costs, LOS, Monthly Summary, PG Summary, Uncertainty-Grades, and Uncertainty-Years.

Raw model output data is also generated and is saved in the Comma Separated Value format type. The data are separated into four categories labeled End Strength, End Strength by FY, Simulation Events, and Event & End Strength Comparison. These reports and data can be accessed via the Navy Total Force Strength Management System Graphical User Interface's Reports Screen, or Scenario Details Screen. However, neither this author nor the SEED Center technical staff has been able to successfully download any of the data files generated by NTFSM. A snapshot of the Navy Total Force Strength Management System Graphical User Interface Reports Selection Window is shown in Figure 5.

Figure 5.   Navy Total Force Strength Management System Graphical
User Interface Reports Selection Window

Source: Navy manpower programming and budget system. (n.d.). Accessed December 9, 2015. https://nmpbst1.n10.npc.navy.mil/pls/nmpbstst/f?p=221:1: 15989421618401:
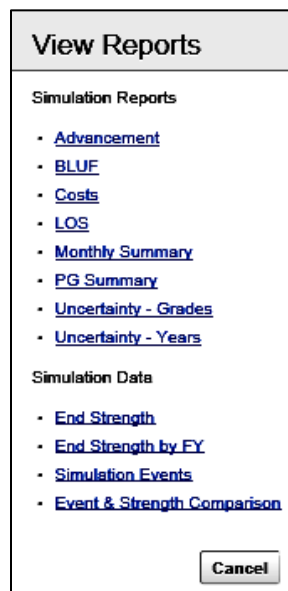
This study focuses on the Monthly Summary and Uncertainty-Years Reports. The Monthly Summary Report is generated in the format required by the Manpower Budgeting Office. The Monthly Summary Report includes: Losses by month, broken down by Prior Service Gains and Non-Prior Service Gains (new recruits); Losses by month, broken down by Attrition losses; Expiration of Active

Obligated Service (EAOS) Loses; Retirement Losses; and Trainee Losses. An example Monthly Summary Report is shown in Figure 6.

Figure 6.   Navy Total Force Strength Model Monthly Summary Report

Start: FY15 - OCT   Number Of FYs: 1   Population Group: Active # Executions: 30

For sims that do not start in Oct, Report will use history for missing months data

Strength	Prev Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
Total with OCs	266,703	266,584	266,466	266,346	266,225	266,110	265,990	265,871	265,754	265,634	265,516	265,396	265,278	
Enlisted OCs	0	0	0	0	0	0	0	0	0	0	0	0	0	
Total without OCs	266,703	266,584	266,466	266,346	266,225	266,110	265,990	265,871	265,754	265,634	265,516	265,396	265,278	
WYA by Month	0	266,644	266,525	266,406	266,286	266,167	266,050	265,930	265,812	265,694	265,575	265,456	265,337	

Gains		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
PSG Gains		59	36	37	62	55	45	45	37	23	35	27	23	486
ADOS		0	1	0	0	0	0	0	0	0	0	0	0	1
Prior Service		33	20	12	31	25	17	14	12	6	6	4	4	185
Other Gains		26	16	25	32	30	28	31	25	17	29	23	19	299
NPS Gains		2,890	2,525	2,361	2,902	2,568	2,228	2,642	3,250	2,757	3,590	2,970	2,678	33,362
TEAOS 0 to 3 Years		0	0	3	0	0	0	2	0	0	1	2	0	7
TEAOS 4 Years		2,867	2,491	2,359	2,889	2,552	2,220	2,619	3,212	2,741	3,572	2,958	2,664	33,144
TEAOS 5 Years		14	24	0	10	8	5	11	23	14	14	9	10	143
TEAOS 6+ Years		8	11	0	3	8	3	11	15	1	3	2	4	69
Total: Gains		2,949	2,562	2,399	2,964	2,623	2,273	2,687	3,287	2,780	3,625	2,998	2,701	33,848

Losses		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Attrition Losses		1,249	1,095	1,129	1,396	1,155	1,102	1,350	1,801	1,304	1,602	1,279	1,281	15,743
Physical		426	406	492	688	460	397	476	473	604	814	612	576	6,423
Hardship		29	47	24	13	30	30	38	46	19	27	22	19	346
Cause		601	492	462	547	476	508	645	649	452	599	423	396	6,250
Miscellaneous		193	151	151	149	189	166	191	633	229	162	222	290	2,724
EAOS Losses		1,057	792	696	1,000	934	696	859	884	839	1,276	939	769	10,741
Zone A : LOS <= 6 years		738	510	444	698	598	435	573	562	568	936	629	497	7,189
Zone B : LOS 7 to 10 years		228	208	182	208	263	190	223	245	202	250	246	211	2,655
Zone C : LOS 11 to 14 years		74	62	57	80	60	62	49	66	57	71	52	47	737
Zone D : LOS 15 to 20 years		16	12	13	14	12	9	14	11	11	17	12	13	154
Zone E : LOS >= 21 years		0	0	0	0	2	1	0	0	0	1	1	1	6
Retirement Losses		411	454	401	387	366	361	342	398	477	517	515	461	5,090
Trainee Losses		351	338	292	301	283	234	256	320	281	349	385	308	3,699
Total: Losses		3,067	2,680	2,518	3,085	2,739	2,393	2,807	3,404	2,900	3,743	3,117	2,819	35,273

Source: Navy manpower programming and budget system. (n.d.). Accessed December 9, 2015. https://nmpbst1.n10.npc.navy.mil/pls/nmpbstst/f?p=221:1: 15989421618401

Notice that the first line of the report shown in Figure 6 lists the simulation start month and fiscal year, the number of fiscal years the simulation was run for, the population group, and the number of times the simulation was executed. The simulation for the scenario that generated the Monthly Summary Report shown in Figure 6 was executed thirty times. In other words, the simulation ran through thirty iterations of this particular scenario. Notice also in Figure 6 that only one number is reported for each of the outputs listed in the Monthly Summary Report. The numbers shown in the report are the estimated means, which were calculated from the output of thirty iterations of the NTFSM simulation. NTFSM, however, is a stochastic model and therefore means by themselves provide

insufficient insight without some measure of variability, such as a standard deviation or standard error.

The Uncertainty-Years Report includes estimated means and standard errors for Begin Strength, Reenlistments, Short and Long Extensions, Expiration of Active Obligated Service (EAOS) Losses, Retirement Losses, OCS Starts, OCS Graduations, OCS Failures, Attrition Losses, Prior Service Gains, Recruit Gains, Recruit Losses, Unexamined Advancements, Demotions, Examined Advancements, and End Strength, broken down by fiscal year. Since the Uncertainty-Years Report offers a measure of the variance of the distribution of NTFSM outputs, the outputs this study's analysis focuses on were chosen from this report. An example Uncertainty-Years report is shown in Figure 7.

Figure 7.   Navy Total Force Strength Model Uncertainty-Years Report

Start: FY15 - OCT   Number Of FYs: 1   Population Group: Active # Executions: 30
For sims that do not start in Oct, Report will NOT use history for missing months data

Uncertainty Report - Years

		Begin Strength	Reenlist-ment	Extensions Short	Long	EAOS Losses	Retirement Losses	OCS Starts	OCS Grads	Failures	Attrition Losses	PS Gains	Recruit Gains	Losses	Unexamined Advancements	Demotions	Examined Advancements	End Strength
FY15	Estimate	266,703	40,861	17,271	6,529	10,741	5,090	0	0	0	15,743	486	33,362	3,699	49,910	5,518	45,282	265,278
FY15	Std. Error	0	134	103	74	94	31	0	0	0	126	22	211	71	167	84	69	4

Estimated mean values (first line of data) are the total values for the fiscal year shown in the rightmost column. Source: Source: Navy manpower programming and budget system. (n.d.). Accessed December 9, 2015. https://nmpbst1.n10.npc.navy.mil/pls/nmpbstst/f?p=221:1:15989421618401

F.   SIMULATION RUN TIME OVERVIEW

The run time for a single iteration of a NTFSM scenario depends on the user-defined time horizon and the current traffic on the NMPBS server network. A single iteration of a NTFSM scenario which projects over a time-horizon consisting of a single fiscal year typically takes anywhere from five to 30 minutes. Once the simulation has completed, a report set is generated and NTFSM closes access to the Policy Screens so that modification of the NTFSM scenario's policies cannot occur. Chapter IV of this thesis contains a more in depth assessment of NTFSM's run time.

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III. EXPERIMENT DESIGN AND IMPLEMENTAION

This chapter discusses the use of design of experiments (DOE) to generate NTFSM output that covers a broad range of possible scenarios to be analyzed. In order to develop a design of experiments that provides insight into the overall behavior of NTFSM, an efficient design that allows for the analysis of many possible response surfaces is selected.

A. DESIGN OF EXPERIMENTS

Applying design of experiments to simulations enables us to gain insight into the underlying system of processes that lead to the generation of simulation output values. Simulation output values provide little meaningful information unless the proper context is applied. Designs of experiments enable us to better understand the system in which those output values arise and to explore the effect of potential policy changes on those systems (Kleijnen, Sanchez, Lucas, & Cioppa, 2005). Designs of experiments allow us to run a set of experimental scenarios which efficiently sample from the total spectrum of possibilities. The data collected from a design of experiment can then be used to develop meta-models that can provide insight on which, and to what extent, simulation inputs affect simulation outputs.

B. DESIGN SELECTION

There are a number of considerations that help guide in the selection of an appropriate design of experiments. A number of choices along a spectrum of complexity give the designer flexibility in the approach, although time and computing resources remain a constraint (Kleijnen et al., 2005). This study relies on the Navy Total Force Strength Management System for the implementation and execution of a design of experiments that has the ability to generate a good representation of the response space. The Navy Total Force Management System is constrained by the available computing capacity of the NMPBS testing server on which it is housed; therefore, the only feasible designs for this study

are those which require a relatively small amount of computing resources while still allowing for the analysis of many diverse response surfaces. Latin hypercube designs arise as a good candidate for this study. These designs are well suited to studies in which gaining a better understanding of the response surface is a primary goal, as they enable the fitting of many diverse response surfaces (Sanchez & Wan, 2012). Further efficiency and improved space-filling properties can be gained by using a nearly orthogonal Latin hypercube (NOLH) design (Cioppa & Lucas, 2007)

Traditionally, a complete understanding of a response surface could be achieved with a full factorial design that iterates through every possible factor value combination. Unfortunately, this requires an extremely large amount of computing resources as designs grow exponentially as factors and levels are added and quickly become unmanageable. For example, a full factorial design that explores a single replication of only seven factors, each of which has only 10 possible settings, would consist of 282,475,249 design points. To put this in perspective, if each design point was run 30 times and it took only one second to process a run, then it would take approximately 268 years to run the entire design. Nearly orthogonal Latin hypercube designs allow for a thorough analysis of the response while requiring only a small fraction of the number of design points of a traditional full factorial design due to their space-filling ability. A NOLH design can explore seven factors while only requiring 17 design points. To put this in perspective, if each design point were run 30 times and it took one second to execute one run, then it would only take about 8.5 minutes to run the entire design. NOLH designs are able to achieve this extreme level of efficiency by efficiently scattering design points throughout the design space in a way that achieves a space-filling pattern that is able to capture a very large portion of the range of possibilities while requiring a very small number of design points.

C.   FACTOR SELECTION

Simulation analysis and design of experiments terminology refers to a 'factor' as a parameter, variable, or input to a simulation. The choice of factors for a design of experiments depends on the intent of the experiment, the characteristics of the available factors, and the computing resources available to run the experiment (Kleijnen et al., 2005). The number of factors chosen for this study is mainly influenced by the availability of computing resources. Although it would be ideal to explore all 12 of NTFSM's Economic Coefficients, the NMPBS testing server, on which NTFSM is currently housed, does not have the computing capacity required to run the 65 design points required for a 12-factor NOLH design using the SEED Center's online design spreadsheet. A NOLH design that explores seven factors, however, requires only 17 design points and therefore needs approximately a quarter of the time and computing resources of a 12 factor (or 65 design point) NOLH design. Using more than seven factors, because of the nature of NOLHs, would require a design consisting of at least 33 design points, which would require about twice the processing time to complete and could potentially cause a strain on the computing resources of the NMBPS testing server. Therefore, a seven-factor NOLH design was chosen for this study. The NTFSM economic coefficients that were chosen as factors for the design are shown in Table 1. These economic coefficients are those that pertain to the events that are either the most important, or contain the most uncertainty and highest variability and therefore are the most difficult to accurately project using the current system.

Table 1.　　　List of Factors Used to Build Design

Event	Unemployment	Pay
Reenlistments	X	X
Long Extensions	X	
Prior Service Gains		
Recruit Losses	X	X
Attrition Losses	X	X
Retirement Losses		

X's denote Economic Coefficients used as factors in the design.

D.　FACTOR RANGE DETERMINATION

In order to produce a NOLH design, a suitable range of values for each of the chosen factors must first be determined. A recent Center for Naval Analysis study into the effects of economic variables and Navy enlisted retention titled *The Economy and Enlisted Retention in the Navy* (Pinelis & Huff, 2014) found that economic variables, including the national unemployment rate and the real disposable personal income growth rate, could have as much as a 25.1 percent positive effect on enlisted retention in the Navy when the state of the economy is extremely weak, and as much as a –20.9 percent negative effect on enlisted retention in the Navy when the state of the economy is extremely strong. These results were used as the basis to determine an appropriate range of values for the seven factors selected. The NOLH design was generated using a range of –30 to 30 for each factor. These values are meant to be conservative bounds that represent the most extreme economic situations and are based on the findings of (Pinelis & Huff, 2014).

E.　NOLH DESIGN GENERATION

The NOLH design was generated using the NOLH worksheet available for download from the SEED Center website (https://harvest.nps.edu/software.htm). The worksheet calculates the factor values for each design point based on the ranges selected. The NOLH design that was generated consists of 17 design points for seven factors and is able to fill the design space rather well. Figure 8

shows a pairwise plot that displays the NOLH design projected into all the two-dimensional subspaces. Notice how the data points are distributed and effectively fill the design space. Moreover, each column of the design matrix is nearly orthogonal to the others; thereby, guaranteeing minimal confounding between estimates.

Figure 8.   Scatterplot Matrix for NOLH Design
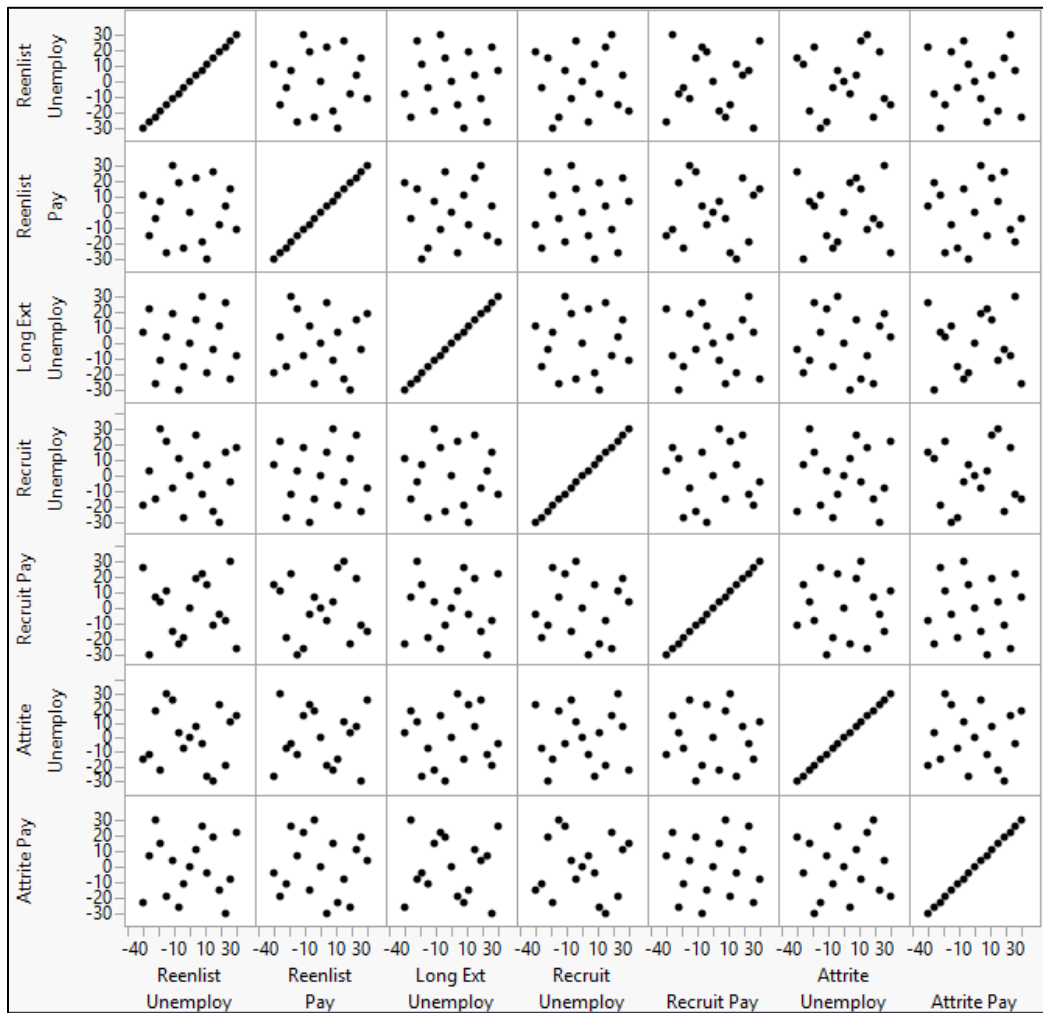
F.   IMPLEMENTATION OF NOLH DESIGN

This study relies on the Navy Total Force Strength Management System Graphical User Interface for the implementation and execution of the NOLH design, and also for the collection of the output data that the design generates.

Currently, the only way to implement the design is by manually creating a unique NTFSM scenario for each data point and modifying the selected factors according to their designed values. This process is extremely time-consuming and is prone to mistakes, so extra care was taken to ensure the integrity of the design remained intact. The implementation of a design of experiments is better suited to be handled by a software program; however, the Navy Total Force Strength Management System Graphical User Interface does not currently allow for this. It is recommended that this capability be added to NTFSM to enable future analysts to more effectively use it.

Utilizing the Navy Total Force Strength Management System Graphical User Interface, 17 unique NTFSM scenarios, one each for every design point, were created and titled accordingly. The scenarios were initialized to use fiscal year 2014 manpower and personnel data. NTFSM was run to project one fiscal year into the future (FY2015). Fiscal year 2014 data was selected because it was the most recent full fiscal year data available. Once the scenarios were created and initialized, a random five-digit seed was assigned to each scenario. The scenarios were then run 30 times each—for a total of 510 NTFSM test runs. The outputs of the 30 runs were then, very carefully, copied from the Uncertainty-Years reports that were generated by each scenario and pasted into a spreadsheet. The spreadsheet was then formatted into a Comma Separated Value file so that the data could be more easily transferred, manipulated, and analyzed.

The 17 randomly generated five digit seed values were populated using R, which is a programing language commonly used for statistical computing (https://www.r-project.org/). A vector consisting of the numbers 0 through 9 was created and assigned to the variable "X." The sample() function was then used to randomly select five numbers from that vector with replacement. Figure 9 shows the R script which was used as well as an example of a five-digit seed.

Figure 9. R code Used to Generate Random Five-digit Seeds

```
> # create vector of numbers and assign to variable X
> X <- c(0:9)
> # select 5 numbers from X variable with replacement
> sample(X,5,T)
[1] 7 5 1 3 5
```

G.   DATA GENERATION FOR OUTPUT DISTRIBUTION ANALYSIS

When running multiple iterations of a NTFSM scenario, the Navy Total Force Strength Management System Graphical User Interface does not include the outcome of every simulation run in any of its reports. This information could theoretically be collected and calculated from the CSV output files that NTFSM generates for each scenario; however, this author, as well as the SEED Center technical staff, was unable to successfully download these files. The Uncertainty-Years report is the only report generated by NTFSM that gives any indication of the variability of a scenario's output, but, although this is useful information, it does not give much insight on the distribution of NTFSM's output. In order to gain a better understanding of the distributions of NTFSM's output, a set of 100 identical scenarios (other than the random number seed) was created. The scenarios were set up to use fiscal year 2014 manpower and personnel data to project one year into the future (FY2015). All NTFSM inputs were kept at their default values. A random five-digit seed was generated for each of the 100 scenarios in R, using the before mentioned method. The outputs of the 100 scenarios were then manually copied from the Uncertainty-Years reports that were generated by each scenario and pasted into a spreadsheet. The spreadsheet was then formatted into a Comma Separated Value file so that the data could be more easily transferred and analyzed.

25

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IV. ANALYSIS AND RESULTS

This chapter describes the analysis and meta-modeling of the NTFSM output data gathered from the NOLH design of experiments. After verifying NTFSM's ability to produce repeatable results, and assessing the stochastic variation and distribution of NTFSM, the mean values of the design point outputs are used as observations to build a set of Ordinary Least Squares (OLS) regression models. These models give insight into the underlying processes inherent to NTFSM and the effects that the explored factors have on NTFSM's output.

A. ANALYTICAL TOOLS

Collection and organization of the data was accomplished using Microsoft Excel 2010. The data was then formatted as CSV files in order be more easily saved and transferred. Analysis and meta-modeling of the resulting CSV data files were performed using JMP Pro version 11.0.0.[2]

B. ASSESSMENT OF NTFSM'S ABILITY TO PRODUCE REPEATABLE RESULTS

It is extremely important to ensure that NTFSM's output is repeatable before NTFSM can leave the testing phase. The repeatability of NTFSM output is a big concern for N100. The manpower and personnel forecasts and analyses that N100 generates are used by top-level decision makers when considering changes to Navy-wide manpower and personnel policies and must be able to stand up to extreme scrutiny. Therefore, independent verification of results by multiple manpower and personnel analysts is necessary. This independent verification cannot be accomplished unless NTFSM output can be repeated.

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[2] More information about JMP Pro statistical software can be found on their website at http://www.jmp.com/en_us/home.html.

1. Single Run Output Repeatability Assessment

To test NTFSM's ability to repeat the results of a single simulation run of a scenario, two identical NTFSM scenarios were created. The scenarios were set up to run one iteration of the scenario and use fiscal year 2014 manpower and personnel data to project one year into the future (FY2015). All scenario inputs were kept at their default values and each scenario used the same five digit random seed (41701), which was generated using the R coding language. The Monthly Summary reports generated by each scenario were then visually inspected for any differences. No differences in the Monthly Summary reports were observed. That is, the two scenarios precisely repeated each other's results. This experiment was conducted a second time and the seed used was modified (66389). The results of this experiment were consistent with the first, i.e., both scenarios, using the same seed, generated identical Monthly Summary reports. It was also observed that the Monthly Summary reports generated in the first experiment varied greatly from the Monthly Summary reports generated by the second experiment even though the only difference between the two experiments was the seeds used. This result proves that NTFSM output can depend of the random seed chosen. Appendix B contains the Monthly Summary reports generated by these two experiments.

2. Multiple Run Output Repeatability Assessment

To test NTFSM's ability to repeat the results of multiple simulation runs of a scenario, two identical NTFSM scenarios were created. The scenarios were set up to simulate five iterations of the scenario and use fiscal year 2014 manpower and personnel data to project one year into the future (FY2015). All scenario inputs were kept at their default values and each scenario used the same five digit random seed (37295), which was generated using the R coding language. The Monthly Summary reports generated by each scenario were then visually inspected for any differences. No differences in the Monthly Summary reports

were observed. The two scenarios repeated each other's results. Appendix B contains the Monthly Summary reports generated by this experiment.

C. SELECTION OF THE NTFSM OUTPUTS TO BE ANALYZED AND USED AS RESPONSES FOR META-MODELS

Since the Navy Total Force Management System Graphical User Interface only produces a measure of variability for the outputs listed on the Uncertainty-Years report, these were the only NTFSM outputs considered for analysis and meta-modeling. This study focuses on the NTFSM outputs listed on the Uncertainty-Years report which pertain to End Strength, to include enlisted losses and enlisted gains. The specific outputs selected for analysis and meta-model responses are listed in Table 2.

Table 2.   List of NTFSM Outputs Selected for Analysis and Meta-Model Responses

	Outputs
1	End Strength
2	Attrition Losses
3	Retirement Losses
4	Recruit Losses
5	EAOS Losses
6	Prior Service Gains
7	Recruit Gains

D. DISTRIBUTION ANALYSIS OF NTFSM OUTPUT

When running multiple iterations of a NTFSM scenario, the Navy Total Force Strength Management System Graphical User Interface does not include much information about the distribution of outputs in any of its reports. To gain a better understanding of the distribution of NTFSM's output and the behavior of the model as a whole, 100 independent but identical (other than the random number seeds) scenarios were manually generated. An analysis of the distribution of the selected output of these 100 scenarios was conducted and it

was found that all of the selected outputs with the exception of End Strength were approximately normally distributed. A detailed analysis of the distribution of Attrition Losses and End Strength follows. A summary of the distribution of Retirement Losses, Recruit Losses, EAOS Losses, Prior Service Gains, and Recruit Gains can be found in Appendix C.

1. Analysis of the Distribution of the Attrition Losses Output Data

a. Descriptive Statistics

Descriptive statistics for 100 independent observations of the Attrition Losses output, which are in units of enlisted Sailors, were calculated, the observations ranged from 9849 to 10312. Other relevant descriptive statistics are summarized in Figure 10.

Figure 10. Summary of Descriptive Statistics for Attrition Losses Output

Summary Statistics	
Mean	10033.270
Std Dev	97.828
Std Err Mean	9.783
Upper 95% Mean	10052.681
Lower 95% Mean	10013.859
N	100.000
Minimum	9849.000
Maximum	10312.000
Median	10034.500

b. Distribution Fitting

A distribution was fit, and it was found that the data are approximately normally distributed with an estimated mean of 10033.27 and an estimated standard deviation of 97.83. These parameter estimates, as well as their upper and lower 95% confidence intervals, are shown in Figure 11.

Figure 11. Parameter Estimates for Normal Distribution Fit to Attrition
Losses Data

Parameter Estimates				
Type	Parameter	Estimate	Lower 95%	Upper 95%
Location	μ	10033.270	10013.859	10052.681
Dispersion	σ	97.828	85.894	113.645

c.   *Goodness-of-Fit Testing*

In order to gain a better understanding to how well the Attrition Losses data matches a normal distribution, a histogram, box plot, and normal quantile plot were generated for the data and compared to a histogram, box plot, and normal quantile plot that was generated using 100 standard normal observations. Normal data tend to stay on the diagonal red line shown on a normal quantile plot and histograms of normal data tend to appear bell shaped in form. No indication of a reasonable difference between the two sets of plots is visually apparent when compared side-by-side. Figure 12 shows a side-by-side comparison of a histogram, box plot, and normal quantile plot for the Attrition Losses data (left) and 100 observations generated from of a standard normal distribution (right).

Figure 12. Side-by-side Comparison of a Histogram, Box Plot, and Normal Quantile Plot for the Attrition Losses Output Data (left) and 100 Observations Generated from a Standard Normal Distribution (right)
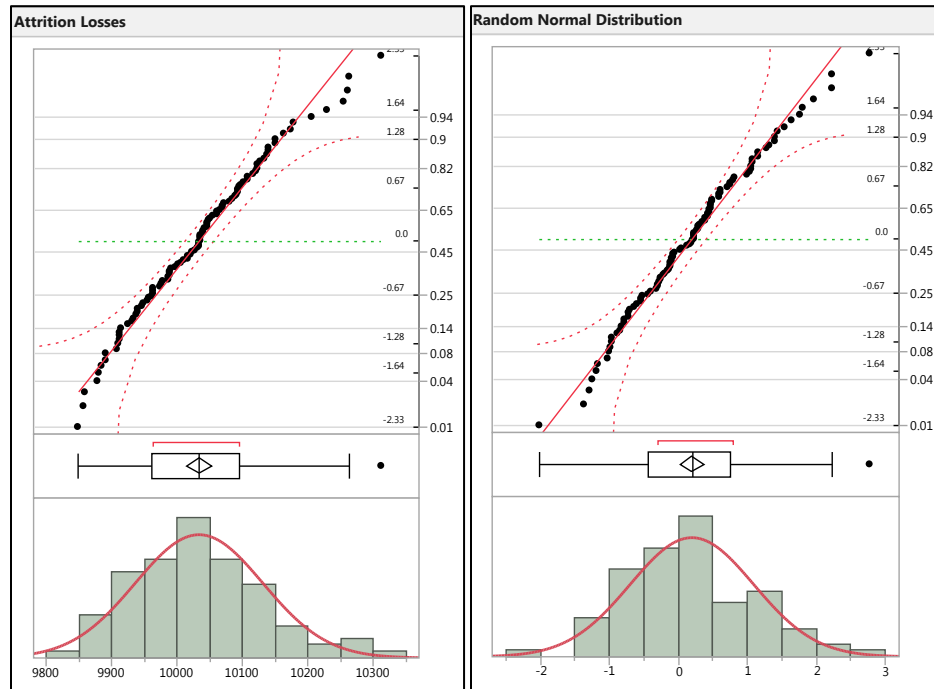
Normal Quantile Plots appear at the top, Box Plots are shown in the center, and Histograms are shown on the bottom, of the two charts.

In order to conduct a more quantitative goodness-of-fit test a Shapiro-Wilk goodness-of-fit test was performed. The Shapiro-Wilk goodness-of-fit test assesses the null hypothesis that the data are from a normal distribution. Statistical standards usually require for the null to be rejected at a *p-value* of less than 0.05. A *p-value* of .184 was obtained from the Shapiro-Wilks goodness-of-fit test performed on the Attrition Losses data; therefore, the null hypothesis was not rejected and it can be reasonable determined that the Attrition Losses output data are approximately normally distributed. A summary of the results of the Shapiro-Wilk goodness-of-fit test conducted on the Attrition Losses data is shown in Figure 13.

Figure 13. Summary of the Results of the Shapiro-Wilk goodness-of-Fit
Test Conducted on the Normal Distribution Fitted to the Attrition
Losses Data

Goodness-of-Fit Test	
Shapiro-Wilk W Test	
W	**Prob<W**
0.982	0.184
Note: Ho = The data is from the Normal distribution. Small p-values reject Ho.	

P-value is indicated by the value listed as **Prob<W.**

2. Analysis of the Distribution of the End Strength Output Data

a. *Descriptive Statistics*

Descriptive statistics for 100 independent observations of the End
Strength output, which are in units of Enlisted Sailors, were calculated; the
observations ranged from 265266 to 265288. The estimated standard error for
End Strength (3.8 Enlisted Sailors) is several orders of magnitude smaller than
the estimated mean. This indicates that there is a very small amount of
stochastic variability in NTFSM's End Strength output. Other relevant descriptive
statistics are summarized in Figure 14.

Figure 14. Summary of Descriptive Statistics for End Strength Output

Summary Statistics	
Mean	265277.04
Std Dev	3.848
Std Err Mean	0.385
Upper 95% Mean	265277.80
Lower 95% Mean	265276.28
N	100.000
Minimum	265266.00
Maximum	265288.00
Median	265277.00

b.   *Distribution Fitting*

An attempt was made to fit a distribution to the End Strength output data, and, unlike the other selected outputs, it was found that the data were not normally distributed. A Shapiro-Wilk goodness-of-fit test that was performed on a normal distribution that had been fit to the data resulted in a *p-value* of 0.0215. This results in the rejection of the null hypothesis that the data are normally distributed at the commonly used .05 significance level.   Several other common distributions were also fit to the data, including a gamma, Weibull, exponential, log normal, normal 2 mixture, and generalized logarithm distribution, none of which, however, had a Shapiro-Wilk *p-value* greater than 0.05. The End Strength output data does not seem to fit any of the commonly used statistical distributions. A histogram, box plot, and normal quantile plot of the End Strength data are shown in Figure 15. One can observe from the quantile plot that with such a short range of output, the discrete nature of the response makes it significantly different than a continuous normal. A summary of the parameter estimates and results of the Shapiro-Wilk goodness-of-Fit test for a normal distribution that was fit to the data is shown in Figure 16.

Figure 15.   Quantile Plot Histogram, Box Plot, and Normal Quantile Plot
for the End Strength Output Data
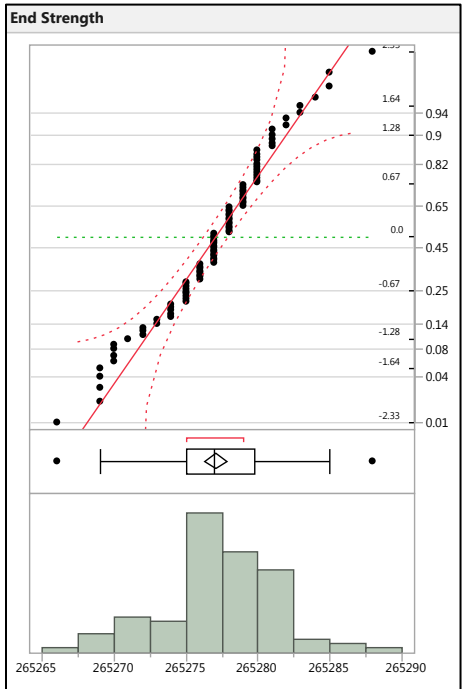
Figure 16. Parameter Estimates and Summary of the Results of the
Shapiro-Wilk Goodness-of-Fit Test for a Normal Distribution Fit
to the End Strength Data

Parameter Estimates

Type	Parameter	Estimate	Lower 95%	Upper 95%
Location	μ	265277.04	265276.28	265277.80
Dispersion	σ	3.848	3.378	4.470

-2log(Likelihood) = 552.294095224667

Goodness-of-Fit Test

Shapiro-Wilk W Test

W	Prob<W
0.970	0.021

Note: Ho = The data is from the Normal distribution. Small p-values reject Ho.

P-value is indicated by the value listed as **Prob<W.**

E. INITIAL ASSESSMENT OF NOLH DESIGN OF EXPERIMENTS OUTPUT DATA

After reviewing the output data from the Uncertainty-Years reports generated from the design of experiments, it was noticed that the output data for enlisted Officer Candidates, Start, Graduation and Failures, had values of zero for each of the 17 design points. After reviewing all available NTFSM documents, this author could not find an explanation for this result but speculates that either: (1) Officer Candidate data was not contained in the fiscal year 2014 data used by the scenarios, (2) Officer Candidate data must be entered into NTFSM by the user prior to running the simulation, or, (3) because NTFSM is still in the testing phase, its capability to track Officer Candidates is still in development. It was also noticed that there was an extremely small amount of stochastic variation in the End Strength output. The estimated mean End Strength results of all 17 design points ranged from 265,276 to 265,279—which is a difference of only three, this seems like a very small amount of variation given the wide range of factor values explored in the design.

F. ANALYSIS AND METAMODELING OF OUTPUT GENERATED BY THE NOLH DESIGN OF EXPERIMENTS

Meta-models help provide insight on the underlying system of processes inherent to a simulation by providing information on which, and to what extent, simulation inputs affect simulation outputs. By using regression techniques that use simulation outputs as response variables and simulation inputs (factors) as prediction variables, meta-models produce estimated coefficient values that quantify how simulation factors affect simulation output. This section provides a description of the seven meta-models (one for each of the selected NTFSM outputs) that were analyzed by this study.

1. Meta-Modeling Methodology

Seven independent stepwise regressions were conducted, each one utilizing a different NTFSM output as the response variable. A common approach

to building linear models is to start with a wide scope and include all predictor variables as well as possible interaction and nonlinear terms (Crawley, 2013). In this study, all initial stepwise regression models include main effects consisting of the seven NTFSM economic coefficients explored, all two-way and three-way interactions, and 3rd order polynomials. This helps ensure the meta-model's ability to capture any interactions or non-linearity in the data. A minimum Bayesian information criterion (BIC) stopping rule was used to help select which terms should be utilized by the meta-model; this helps prevent overfitting of the model. Stepwise regression is an approach that is used for selecting a subset of effects for a regression model. It is used when there is little theory to guide the selection of terms for a model and the modeler wants to use what seems to provide a good fit (SAS Institute Inc., 2013). Stepwise regression computes estimates that are the same as those of other least squares platforms, but it facilitates searching and selecting among many models (SAS Institute Inc., 2013). Additional information on the Bayesian information criterion, stepwise regressions, and linear regressions can be found in SAS Institute Inc. (2013).

The terms which were selected with the help of stepwise regression were then used as prediction variables in a least squares regression model. The least squares regression models' R-square and adjusted R-square values were screened to verify the model's performance. The R-square value is the proportion of the response variance explained by the input variables, and ranges from zero to one. The R-square and Adjusted R-square values from the accepted models are listed in Table 3. All seven fitted regression models explained well over 90 percent of the responses' variability.

Table 3.　　　R-Square and Adjusted R-Square of Accepted Meta-Models

	R^2	Adj R^2
End Strength	0.910	0.840
Attrition Losses	0.999	0.999
Retirement Losses	0.947	0.94
Recruit Losses	0.989	0.984
EAOS Losses	0.959	0.953
Prior Service Gains	0.875	0.778
Recruit Losses	0.983	0.979

The least squares models were then validated by testing key model assumptions before being accepted. Verification of the accepted models was conducted by comparing the observed output from three independent NTFSM Test scenarios, which were created, to the predicted values produced by the accepted meta-models.

2.　　Overview of the Meta-Model that Was Selected for End Strength

For the End Strength output, a stepwise regression model of all effects and three way interactions and third degree polynomials produced a model with 15 predictor variables and had R-square and Adjusted R-square values of 1.0000 and 0.9997 respectively. This model contained five of the seven NTFSM economic coefficients, five interaction terms and five polynomial terms. This shows that complicated relationships are captured by NTFSM. Many of the interaction and polynomial terms contributed very little to the R-square and Adjusted R-square values and/or had high t-test *p-values*. It was determined that these interaction and polynomial terms did not add sufficient value to the model and were removed, for parsimony. The remaining terms, however, seem to have very small coefficient values given that Navy End Strength is generally in the hundreds of thousands. The final model is summarized in Figure 17.

Figure 17. Parameter Estimates for End Strength Meta-Model

Parameter Estimates				
Term	**Estimate**	**Std Error**	**t Ratio**	**Prob>|t|**
Intercept	265277.47	0.139898	1.9e+6	<.0001 [*]
Reenlist P	-0.034173	0.005407	-6.32	0.0001 [*]
Long Ext U	0.0186663	0.005635	3.31	0.0090 [*]
Recruit P	-0.011765	0.004891	-2.41	0.0396 [*]
Attrite U	0.0750909	0.014977	5.01	0.0007 [*]
Reenlist P*Long Ext U	0.0016202	0.000294	5.51	0.0004 [*]
Attrite U*Attrite U	-0.001038	0.000318	-3.27	0.0097 [*]
Attrite U*Attrite U*Attrite U	-0.000101	2.341e-5	-4.34	0.0019 [*]

The R-square and Adjusted R-square of 0.9102 and 0.8404, respectively, show that the model sufficiently accounts for the variability of the data, however the model utilizes eight parameters and since there are only 17 data points, this model runs the risk of over-fitting the data. Inspection of the t-test *p-values* shows that of the parameters used are highly significant and therefore all eight parameters are kept in the model. Based on the coefficients, the Attrition Losses Unemployment, Reenlistment Pay, and Long Extension Unemployment, economic factors have the greatest effect on NTFSM's End Strength output. The effects these economic factors have on the End Strength output are still extremely small when compared to the intercept estimate of approximately 265,278. An R-square and Adjusted R-square of 0.34 and 0.188, respectively, were obtained from a model built with only these three predictors, which indicates that the other terms in the model still have some effect.

Diagnostic plots of the model indicate that key modeling assumptions are met. The residual versus predicted plot in Figure 18 indicates homoscedasticity of the residuals and the normal quantile plot of the residuals shown in Figure 19 exhibits behavior consistent with normally distributed data—though further investigation into the striped pattern is warranted. For further verification, a Shapiro-Wilk goodness-of-fit test was conducted on a normal distribution fit to the residuals of the End Strength meta-model. Parameter estimates and goodness-of-fit statistics are summarized in Figure 20.

Figure 18. Residuals versus Predicted Values of End Strength Meta-Model
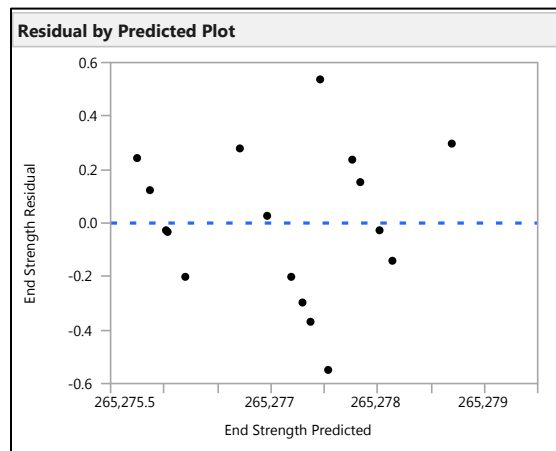
Figure 19. Side-by-Side Comparison of a Normal Quantile Plot of the Residuals for End Strength Meta-Model (Right) and Normal Quantile Plot for Normal Data (Left)
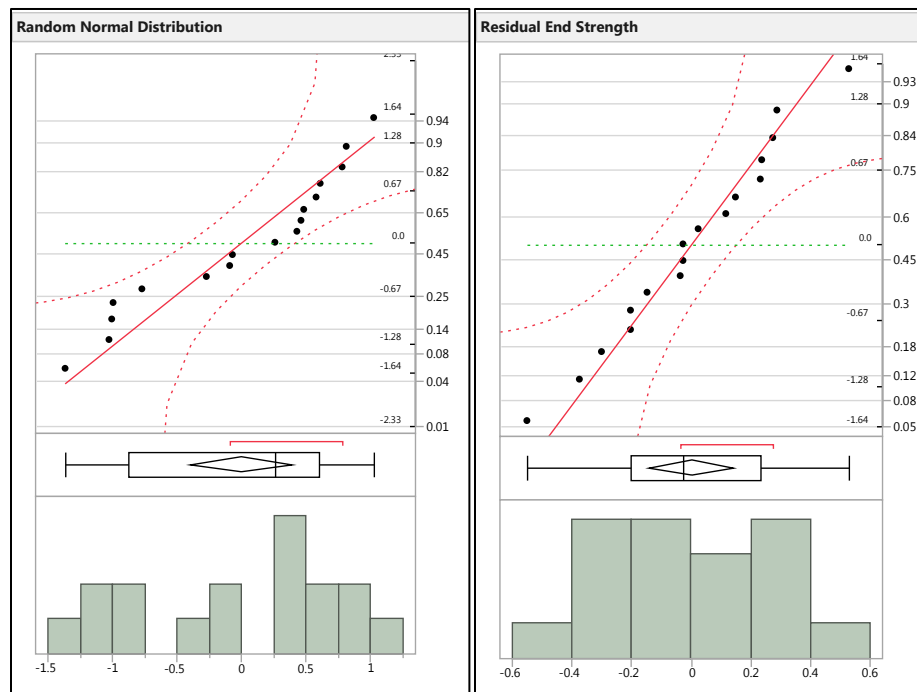
Figure 20. Parameter Estimates and Goodness-of-Fit Statistics for
Normal Distribution Fit to the End Strength Meta-Model
Residuals

Parameter Estimates				
Type	Parameter	Estimate	Lower 95%	Upper 95%
Location	μ	2.739e-11	-0.142864	0.1428641
Dispersion	σ	0.2778633	0.2069442	0.4228882

-2log(Likelihood) = 3.70262463835185

Goodness-of-Fit Test	

Shapiro-Wilk W Test

W	Prob<W
0.985792	0.9918

Note: Ho = The data is from the Normal distribution. Small p-values reject Ho.

3.   Overview of the Meta-Model that Was Selected for Attrition Losses

For the Attrition Losses output, a stepwise regression model of all effects and three way interactions and third order polynomials produced a model with 15 predictor variables that had R-square and Adjusted R-square values of 1.0000 and 1.0000, respectively. The extremely high (i.e., perfect fit) R-square and Adjusted R-square values give indication that the model has been over-fit, so further analysis of the model terms was conducted. The initial model contained five of the seven NTFSM economic factors, five interaction terms and five polynomial terms. It was found that many of the terms contributed very little to the R-square and Adjusted R-square values. A model was created that used only the Attrition Losses Unemployment and Pay economic factors; this model produced an R-square and adjusted R-square of 0.9996 and 0.9994, respectively. Again, almost a perfect fit. When validation of this model was performed, however, it was found that the residuals were not normally distributed. The final model which was selected utilized the Attrition Losses Unemployment as well as the Attrition Losses Pay economic factors and their corresponding 2nd and 3rd order polynomial terms. The final model is summarized in Figure 21.

Figure 21. Parameter Estimates for Attrition Losses Meta-Model

Parameter Estimates				
Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	9774.4582	147.3555	66.33	<.0001*
Attrite U	-608.2732	14.94277	-40.71	<.0001*
Attrite P	3.5402206	6.003497	0.59	0.5663
Attrite U*Attrite U	20.76605	0.326185	63.66	<.0001*
Attrite U*Attrite U*Attrite U	-0.33099	0.023085	-14.34	<.0001*

The R-square and Adjusted R-square of 0.9996 and 0.9994, respectively, show that the model does a very good job of accounting for the variation of the response variable. Based on the coefficients, the Attrition Losses Unemployment, economic factor has the greatest effect on NTFSM's Attrition Losses output. An R-square and Adjusted R-square of 0.84 and 0.83, respectively, were obtained from a model built using only the Attrition Losses Unemployment economic factor, which indicates that this one term explains most of the variation in the model, but the other terms still have a significant effect. All terms except Attrition Losses Pay are highly statistically significant according to their t-test *p-values.* A model that excludes the Attrition Losses Pay term shows signs of non-normality in the residuals and therefore Attrition Losses Pay was kept in the model.

Diagnostic plots of the final model indicate that key modeling assumptions are met. The residual versus predicted plot in Figure 22 sufficiently indicates homoscedasticity of the residuals and the normal quantile plot of the residuals shown in Figure 23 exhibits behavior consistent with normally distributed data. For further verification, a Shapiro-Wilk goodness-of-fit test was conducted on a normal distribution fit to the residuals of the Attrition Losses meta-model. Parameter estimates and goodness-of-fit statistics are summarized in Figure 24.

Residuals Versus Predicted Values of Attrition Losses Meta-Model
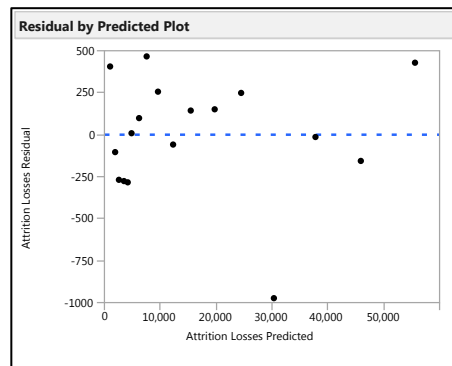
Figure 22. Side-by-side Comparison of a Normal Quantile Plot of the Residuals for Attrition Losses Meta-Model (Right) and Normal Quantile Plot for Normal Data (Left)
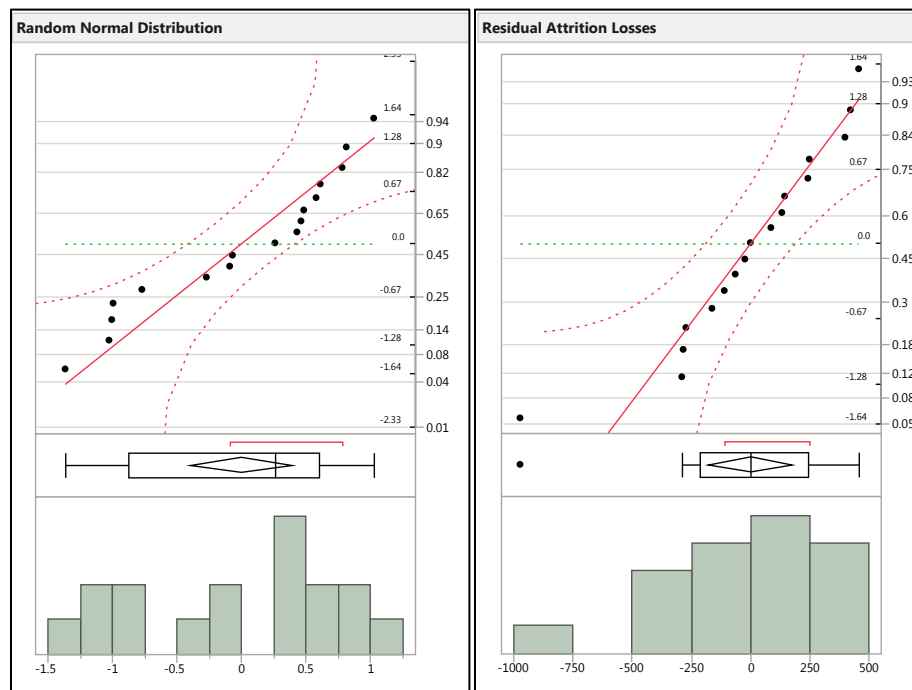
Figure 23. Parameter Estimates and Goodness-of-Fit Statistics for
Normal Distribution Fit to the Attrition Losses Meta-Model
Residuals

Parameter Estimates				
Type	Parameter	Estimate	Lower 95%	Upper 95%
Location	μ	-4.28e-13	-179.8274	179.82743
Dispersion	σ	349.755	260.48697	532.30225

-2log(Likelihood) = 246.38982867376

Goodness-of-Fit Test	

Shapiro-Wilk W Test

W	Prob<W
0.907858	0.0920

Note: Ho = The data is from the Normal distribution. Small p-values reject Ho.

4. Overview of the Meta-Model that Was Selected for EAOS Losses

For the EAOS Losses output, a stepwise regression model of all effects and three way interactions and third order polynomials produced a model with 15 predictor variables that had R-square and Adjusted R-square values of 1.0000 and 1.0000 respectively. Again, a perfect fit. The extremely high R-square and Adjusted R-square values obtained give indication that the model has been over fit, therefore further analysis of the model terms was conducted. The initial model contained six of the seven NTFSM economic factors, four interaction terms and five polynomial terms. It was found that many of the terms contributed very little to the R-square and Adjusted R-square values and by using only two terms, Reenlistment Unemployment and Long Extension Unemployment, a model producing an R-square and Adjusted R-square of 0.9591 and 0.9533, respectively, was obtained. The final model is summarized in Figure 25.

44

Figure 24. Parameter Estimates for EAOS Losses Meta-Model

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	12946.1	350.48	36.94	<.0001*
Reenlist U	325.512	19.077	17.06	<.0001*
Long Ext U	116.361	19.077	6.10	<.0001*

The R-square and Adjusted R-square of 0.959 and 0.953 respectively, show that the model does a very good job of accounting for the variation of the response variable. Based on the coefficients, the Reenlistment Unemployment, economic factor has the greatest effect on NTFSM's Attrition Losses output. Notice that the Reenlistment Pay economic factor does not enter the model, therefore it can be reasonably concluded that the effect that the Reenlistment Pay economic coefficient has on the EAOS Losses output is negligible.

Diagnostic plots of the final model indicate that key modeling assumptions are met. The residual versus predicted plot in Figure 26 sufficiently indicates homoscedasticity of the residuals and the normal quantile plot of the residuals shown in Figure 27 exhibits behavior consistent with normally distributed data. For further verification, a Shapiro-Wilk goodness-of-fit test was conducted on a normal distribution fit to the residuals of the EAOS Losses meta-model. Parameter estimates and goodness-of-fit statistics are summarized in Figure 28.

Figure 25. Residuals versus Predicted Values of EAOS Losses
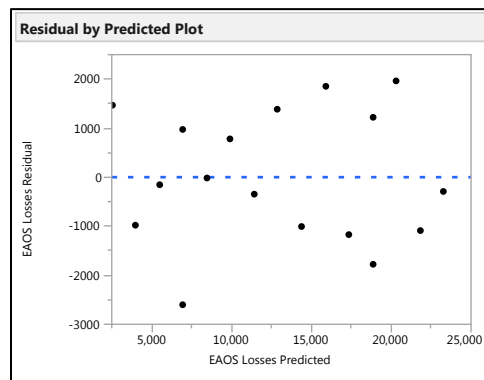
Figure 26. Side-by-side Comparison of a Normal Quantile Plot of the
Residuals for the EAOS Losses Meta-Model (Right) and
Normal Quantile Plot for Normal Data (Left)
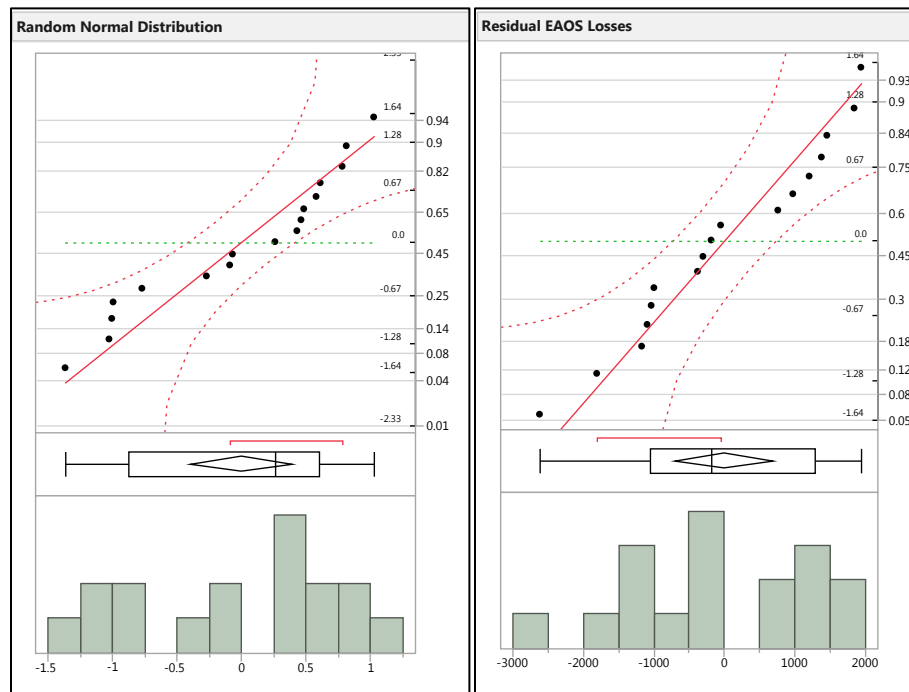
Figure 27. Parameter Estimates and Goodness-of-Fit Statistics for
Normal Distribution Fit to the EAOS Losses Meta-Model
Residuals

Parameter Estimates

Type	Parameter	Estimate	Lower 95%	Upper 95%
Location	μ	-1e-12	-694.989	694.989
Dispersion	σ	1351.72	1006.719	2057.218

-2log(Likelihood) = 292.354380166014

Goodness-of-Fit Test

Shapiro-Wilk W Test

W	Prob<W
0.953	0.504

Note: Ho = The data is from the Normal distribution. Small p-values reject Ho.

5. Comparison of Prediction Estimates and Observed NTFSM Output

To verify the meta-models that were developed, three independent NTFSM scenarios were run to test the meta-models' predictive accuracy. The first test scenario set all seven of the NTFSM economic coefficients explored to the upper bound of 30. The second test scenario set all seven of the NTFSM economic coefficients explored to the lower bound of –30. The third test scenario set each of the seven NTFSM economic coefficients explored to a uniformly distributed random number between –30 and 30. The outputs of these scenarios were compared to the prediction values produced by the meta-models. The NTFSM economic coefficient values used in the third test scenario are listed in Table 4.

Table 4.   NTFSM Economic Coefficient Values Used in the Third Test Scenario

Event	Unemployment	Pay
Reenlistment:	19.61	4.44
Long Extensions:	18.54	0.00
PS Gains:	0.00	0.00
Recruit Losses:	-17.94	5.42
Attrition Losses:	3.64	17.10
Retirement Losses:	0.00	0.00

It was previously determined that the NTFSM outputs explored by this thesis are approximately normally distributed, with the exception of the End Strength output. It was therefore possible to calculate 95 percent upper and lower confidence bounds using the estimated means and standard errors listed on the Uncertainty-Years reports of the three test scenarios described in this section. The distribution of the End Strength output is unknown, therefore 95 percent confidence bounds could not be calculated; instead it was determined sufficient to set the bounds to plus or minus one standard error from the estimated mean. Comparison plots of the prediction estimates and observed NTFSM output values of the End Strength output for each of the three test

scenarios are shown in Figure 29. Comparison plots for the remaining meta-models can be found in Appendix E.

Figure 28. Comparison Plots for End Strength Output
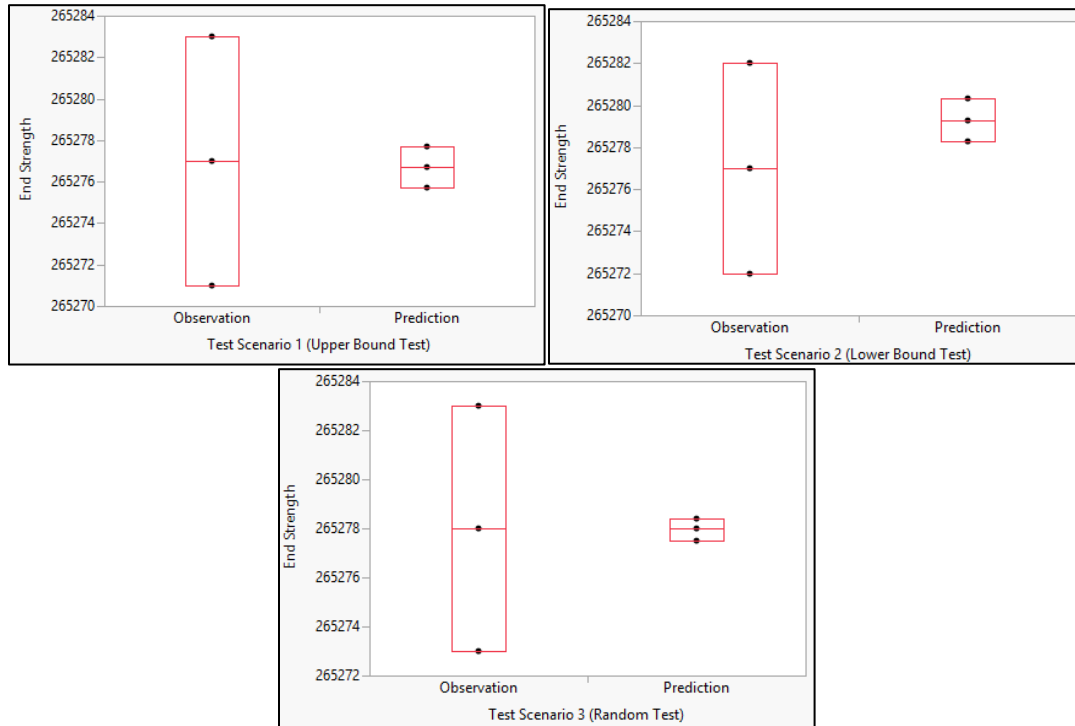
6.   Analysis of the Variance of the End Strength Output

Visual inspection of the comparison plots shown in Figure 29 and of the data generated by the NOLH design of experiments show very little difference in the observed NTFSM End Strength output values. To gain a better understanding of the differences in the End Strength output values, a side-by-side comparison plot was created. The comparison plot shows the End Strength output values with upper and lower bounds of plus or minus one standard error, for each of the 17 design points of the NOLH design of experiments, the upper and lower bounds testing scenarios, and two new extreme scenarios which set the seven NTFSM economic coefficients to the minimum and maximum values allowed by the NTFSM software (-999.99 and 9999.99). It was found that the NTFSM End Strength output from these scenarios are all well within one

standard error of the grand mean of 265,277, therefore it can be reasonably concluded that, even though there is an extreme difference in the input values used for the scenarios, there is no practical difference between the scenarios' End Strength values. Figure 30 shows the comparison plot which was created.

Figure 29. Comparison Plot of End Strength Values of DOE Design Points, Upper and Lower Bounds, and Extreme Upper and Lower Bounds Scenarios
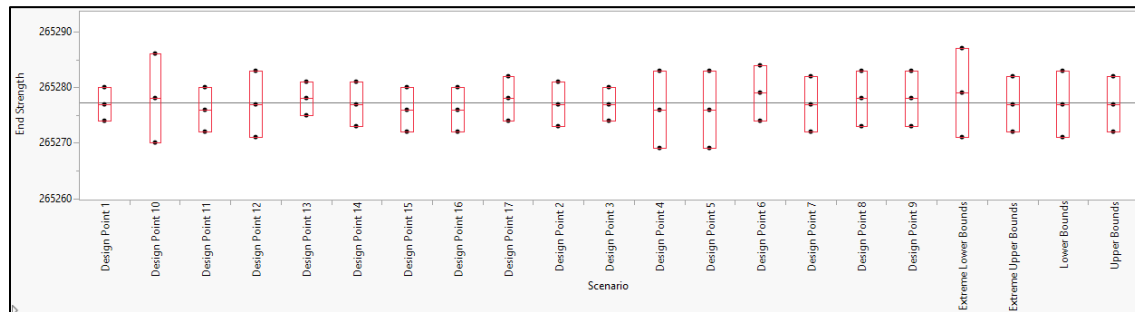
G.   ASSESSMENT OF NTFSM'S RUN TIME

NTFSM is currently housed on an NMPBS testing server. Simulation run time varies depending on a number of variables, including server traffic and the number of fiscal years that are being simulated. The NTFSM simulations in this study were run for a single fiscal year. In the process of running the experiments necessary to answer the research questions that guide this study, the amount of time it took to complete a single NTFSM simulation run, as well as the amount of time it took to complete 30 runs of one experimental design point, were recorded and assessed.

1.   Single Fiscal Year NTFSM Scenario Run Time

In order to better understand the distribution of NTFSM's outputs, 100 identical scenarios were created. The scenarios used unique five-digit seeds and were initialized to use fiscal year 2014 Manpower and Personnel data to project one year into the future (FY2015). The time to run one scenario ranged from 4.65 to 28.28 minutes, with an average run time of approximately eight minutes.

These and other descriptive statistics, as well as a histogram and box plot, of the run time of a single iteration of a NTFSM scenario which projects over a time-horizon consisting of a single fiscal year is summarized in Figure 31.

Figure 30. Histogram, Box Plot, and Descriptive Statistics of the Run Time of a Single Iteration of a NTFSM Scenario that Projects over a Time-Horizon Consisting of a Single Fiscal Year

Summary Statistics	
Mean	7.9854
Std Dev	4.2481336
Std Err Mean	0.4248134
Upper 95% Mean	8.8283219
Lower 95% Mean	7.1424781
N	100
Minimum	4.65
Maximum	28.28
Median	6.625
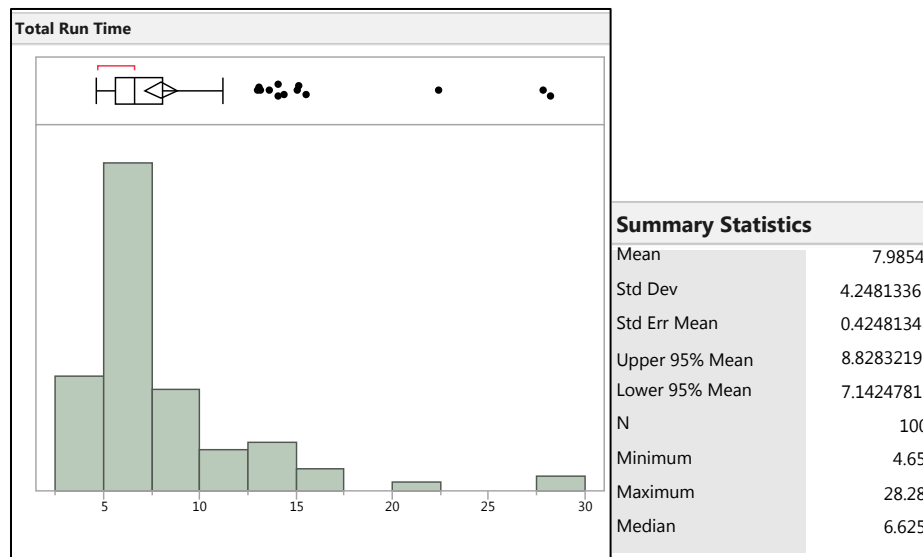
Horizontal axis shows Total Run Time, units are in minutes.

2.   NOLH Design of Experiments Run Time per Design Point

The execution times for 30 runs of each of the 17 design points which make up the NOLH design of experiments utilized by this study were recorded and assessed. The time to run one design point ranged from 2.03 to 10.52 hours, with an average run time of approximately 6.78 hours. Total run time for the entire experiment was approximately 115.34 hours. These and other descriptive statistics, as well as a histogram and box plot, of the run time a single design point are summarized in Figure 32.

Figure 31. Histogram, Box Plot, and Descriptive Statistics of the Run
Time of 30 Iterations of a Single Design Point

Total Run Time

Summary Statistics	
Mean	6.7847059
Std Dev	3.0153402
Std Err Mean	0.7313274
Upper 95% Mean	8.3350508
Lower 95% Mean	5.234361
N	17
Minimum	2.03
Maximum	10.52
Median	6.47
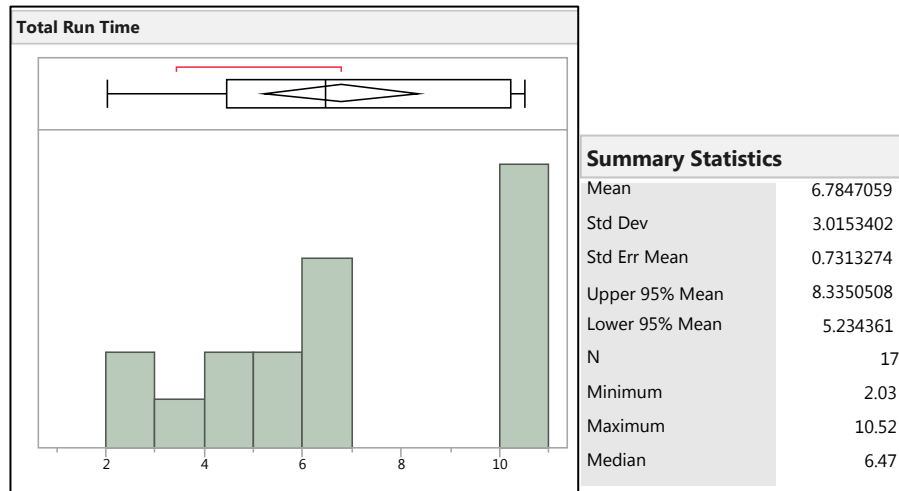
Horizontal axis shows total run time, units are in hours.

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V. CONCLUSIONS

A.   ANSWERS TO RESEARCH QUESTIONS

1.   Are the Results Generated by NTFSM Repeatable?

NTFSM is a stochastic simulation that utilizes seeded random number generation to produce results that vary from run to run. Theoretically, identical scenarios with identical seeds should produce the exact same results. NTFSM's ability to produce identical results however had not been verified. This study conducted two experiments that tested NTFSM's ability to produce repeatable results. The first of which tested whether or not identical NTFSM scenarios which were run for a single iteration produced identical results. The second experiment tested whether or not identical NTFSM scenarios which were run over multiple iterations produced identical results. In both cases it was found that identical NTFSM scenarios which utilize the same seed produce identical results. As a consequence of the experiments, it was also found that identical NTFSM scenarios that do not utilize the same seed do show at least some stochastic variation in their results.

2.   What Is the General Behavior of NTFSM's Main Outputs?

NTFSM is capable of producing numerous outputs including monthly and yearly loss, gain and financial cost estimates broken down by rating, paygrade, years of service, and gender. The scope of this thesis concentrated on the loss and gain estimates that were listed in the Uncertainty-Years report. It was found that when fiscal year 2014 data is used to project one year into the future (FY2015) the EAOS Losses, Retirement Losses, Attrition Losses, Prior Service Gains, Recruit Gains, and Recruit Losses outputs are approximately normally distributed. The End Strength output does not seem to match any of the common statistical distributions and it does not seem to contain very much stochastic variability. Additional study as to why there is such little variability in End Strength is required.

3. How Sensitive Are NTFSM's Main Outputs to Changes in its User-defined Economic Factors?

Due to the limited computing resources available on the NMPBS testing server on which NTFSM is currently housed, only seven of NTFSM's 12 economic coefficients could be explored. Any effects that the remaining five economic factors have on NTFSM output were not captured by the meta-models developed in this thesis. Also due to computing resources, the only scenarios that could be explored by this thesis were those which utilized fiscal year 2014 data to project one year into the future (FY2015). The meta-models and sensitivities reported in this thesis are only valid for scenarios that also use fiscal year 2014 data to project one year into the future (FY2015). The details of which, and to what extent, the economic coefficients have an effect on the NTFSM outputs explored are contained in Chapter V and Appendix D of this thesis. Table 5 shows a summary of which of the NTFSM economic coefficients explored have an effect on the NTFSM outputs explored.

Table 5.   Summary of NTFSM Economic Coefficients that Have an Effect on the NTFSM Outputs Explored

	Reenlistment		Recruit Losses		Attrition Losses		Long Extensions
	Unemployment	Pay	Unemployment	Pay	Unemployment	Pay	Unemployment
Attrition Losses	NO	NO	NO	NO	YES	YES	NO
Retirement Losses	NO	NO	NO	NO	YES	NO	NO
Recruit Losses	YES	NO	NO	NO	YES	NO	YES
EAOS Losses	YES	NO	NO	NO	NO	NO	YES
Prior Service Gains	NO	NO	NO	YES	YES	YES	YES
Recruit Gains	YES	NO	NO	NO	YES	NO	NO
End Strength	NO	YES	NO	YES	YES	NO	YES

All NTFSM outputs explored seem to have at least some level of sensitivity to the seven economic factors explored with the exception of the End Strength output. The coefficients of the parameters of the meta-model developed for the End Strength output are very small, which means the parameters of the model have a very small effect on NTFSM's End Strength output. An End Strength model that uses only the intercept value (265,278) as the End Strength

prediction value, although much simpler, may perform just as well as the meta-model developed for all intents and purposes.

B. RECOMMENDATIONS FOR FUTURE STUDY

This study acts as a proof of concept that simulation analysis and meta-modeling techniques can be applied to NTFSM to gain useful insight on the behavior of the NTFSM simulation. This thesis is constrained in the scope to which these simulation analysis and meta-modeling techniques can be applied due to the computing resources available on the NMPBS testing server on which NTFSM in currently housed. The SEED Center, however, is working on transferring NTFSM to their computing cluster. This will greatly increase the amount of computing resources available for future analysis of NTFSM. To build on the experiments conducted in this thesis, it is recommended that all 12 of NTFSM's economic coefficients and all economic conditions be explored to better understand the interactions and effects that could not be captured by this thesis. Also, due to computing resource constraints, the results of this thesis only apply to NTFSM scenarios that utilize fiscal year 2014 data to project one year into the future (FY2015). If the computing resource constraint was no longer present, however, then NTFSM scenarios that utilize the full spectrum of fiscal year data contained in NTFSM's data repository could potentially be explored and more generalizable results could be produced.

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APPENDIX A. LIST OF NTFSM CAPABILITIES MANDATED BY THE NAVY TOTAL FORCE STRENGTH MODEL PROGRAM PLAN

The following information was taken directly from the Navy Total Force Strength Model Program Plan (Department of the Navy, 2011)

A model capability is defined as critical and fundamental model functionality desired by stakeholders. The Navy Total Force Strength Model capabilities to be developed include:

- Impact of LOS into forecast of future inventory by paygrade. (CAP1)

- Incorporate econometric effects of losses by LOS and paygrade using parameters generated by the Navy Econometric Modeling System (NEMS) to the greatest extent possible. (CAP2)

- Enable the modeling of a wide variety of changes to policy and estimate their impact. (CAP3)

- Provide ability to build multiple scenarios either for a specific date of for the Future Years Defense Plan (FYDP) range, including the ability for users to modify inputs related to economics, losses, gains, advancements, and Navy policy with limited user interaction. (CAP4)

- Provide the ability to perform side-by-side analysis of multiple scenarios to include the ability to visualize and compare input variables. (CAP5)

- Provide the ability to calculate cost and associated metrics to include total cost, promotion and accession costs, and both aggregate and pay-grade work-year averages of a set of strength plans, including validation/updates to underlying cost data. (CAP6)

- Quantify and display risk/uncertainty in forecasts for specific metrics including strength and costs. Estimate the primary sources of risk/uncertainty and the sensitivity of the output to changes in the inputs. (CAP7)

- Automated comparison of strength plans versus actual execution, as well as previous plans versus current plans, including the ability

for users to backcast to evaluate the impact of alternate settings on simulated forecast accuracy. (CAP8)

- Provide comparison between outputs of this model and community-level models. (CAP9)

- Model architecture will support hosting of model, scenarios, (inputs, user comments, etc.) and outputs in a secure Navy environment, such as the Navy Manpower, Programming, and Budget System (NMPBS), and will support data and reporting requirements from the Office of the Secretary of Defense (OSD), Director, MPN Financial Management Division (N10), and other stakeholders minimizing the need for additional transformations or rework. (CAP10)

- Existing capabilities of the existing strength model: (CAP11)

  - Generate strength plans by paygrade and month for a range of fiscal years.

  - Generate scenarios by paygrade and month at varying points of the execution year (i.e.,Actual (A1, A2, A3, etc).

  - Forecast total Expiration of Active Obligated Service (EAOS) actions by month and paygrade.

  - Forecast monthly retirement losses by paygrade and LOS.

  - Forecast attrition losses by month and paygrade.

  - Forecast non-accession gains by month and paygrade.

  - Compute total recruit gains to meet fixed end strength.

  - Compute end strength given fixed accession plan.

  - Forecast automatic grade movements.

  - Forecast advancement plan based on calculated vacancies.

- Enhanced capabilities of the existing strength model that are approved for implementation. (CAP12)

APPENDIX B. MONTHLY SUMMARY REPORTS FOR REPEATABILITY OF NTFSM SCENARIO OUTPUT EXPERIMENTS

Monthly Summary reports for single run output repeatability assessment for Experiment One.

The scenarios were set up to run one iteration of the scenario and use fiscal year 2014 Manpower and Personnel data to project one year into the future (FY2015). All scenario inputs were kept at their default values and each scenario used the same 5 digit random seed (41701).

Monthly Summary Report for the First Scenario (seed 41701)

Start: FY15 - OCT   Number Of FYs: 1   Population Group: Active # Executions: 1
For sims that do not start in Oct, Report will use history for missing months data

Strength	Prev Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Total with OCs	266,703	266,576	266,463	266,353	266,226	266,105	265,992	265,876	265,764	265,632	265,526	265,397	265,277
Enlisted OCs	0	0	0	0	0	0	0	0	0	0	0	0	0
Total without OCs	266,703	266,576	266,463	266,353	266,226	266,105	265,992	265,876	265,764	265,632	265,526	265,397	265,277
WYA by Month	0	266,640	266,520	266,408	266,290	266,166	266,049	265,934	265,820	265,698	265,579	265,462	265,337

Gains	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
PSG Gains	54	30	41	61	70	42	34	34	21	31	27	24	469
ADOS	0	0	0	0	0	0	0	0	0	0	0	0	0
Prior Service	27	14	11	37	38	19	12	11	7	11	5	3	195
Other Gains	27	16	30	24	32	23	22	23	14	20	22	21	274
NPS Gains	2,662	2,288	2,123	2,733	2,343	2,065	2,484	2,958	2,615	3,471	2,936	2,526	31,204
TEAOS 0 to 3 Years	0	0	5	0	0	0	1	0	0	1	1	0	8
TEAOS 4 Years	2,637	2,255	2,118	2,720	2,337	2,049	2,463	2,927	2,603	3,448	2,916	2,508	30,981
TEAOS 5 Years	17	22	0	11	1	9	13	17	11	19	14	14	148
TEAOS 6+ Years	8	11	0	2	5	7	7	14	1	3	5	4	67
Total: Gains	2,716	2,318	2,164	2,794	2,413	2,107	2,518	2,992	2,636	3,502	2,963	2,550	31,673

Losses	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Attrition Losses	791	689	719	889	731	676	899	1,147	829	1,040	914	827	10,151
Physical	253	280	323	437	273	238	316	307	378	534	394	336	4,069
Hardship	17	32	12	9	24	23	20	32	12	14	9	13	217
Cause	408	296	278	351	327	329	441	419	302	394	348	274	4,167
Miscellaneous	113	81	106	92	107	86	122	389	137	98	163	204	1,698
EAOS Losses	1,268	967	880	1,335	1,197	971	1,159	1,240	1,205	1,757	1,274	1,114	14,367
Zone A : LOS <= 6 years	922	664	572	979	811	617	791	837	876	1,339	904	768	10,080
Zone B : LOS 7 to 10 years	242	213	218	258	291	250	291	307	253	307	293	264	3,187
Zone C : LOS 11 to 14 years	84	74	76	86	72	91	60	79	55	86	63	62	888
Zone D : LOS 15 to 20 years	20	15	14	10	22	13	17	17	20	23	14	18	203
Zone E : LOS >= 21 years	0	1	0	2	1	0	0	0	1	2	0	2	9
Retirement Losses	411	455	402	388	368	363	343	402	473	505	543	424	5,077
Trainee Losses	373	320	273	309	238	210	233	315	261	306	361	305	3,504
Total: Losses	2,843	2,431	2,274	2,921	2,534	2,220	2,634	3,104	2,768	3,608	3,092	2,670	33,099

Monthly Summary Report for the Second Scenario (seed 41701)

Start: FY15 - OCT   Number Of FYs: 1   Population Group: Active # Executions: 1

For sims that do not start in Oct, Report will use history for missing months data

Strength	Prev Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Total with OCs	266,703	266,576	266,463	266,353	266,226	266,105	265,992	265,876	265,764	265,632	265,526	265,397	265,277
Enlisted OCs	0	0	0	0	0	0	0	0	0	0	0	0	0
Total without OCs	266,703	266,576	266,463	266,353	266,226	266,105	265,992	265,876	265,764	265,632	265,526	265,397	265,277
WYA by Month	0	266,640	266,520	266,408	266,290	266,166	266,049	265,934	265,820	265,698	265,579	265,462	265,337

Gains	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
PSG Gains	54	30	41	61	70	42	34	34	21	31	27	24	469
ADOS	0	0	0	0	0	0	0	0	0	0	0	0	0
Prior Service	27	14	11	37	38	19	12	11	7	11	5	3	195
Other Gains	27	16	30	24	32	23	22	23	14	20	22	21	274
NPS Gains	2,662	2,288	2,123	2,733	2,343	2,065	2,484	2,958	2,615	3,471	2,936	2,526	31,204
TEAOS 0 to 3 Years	0	0	5	0	0	0	1	0	0	1	1	0	8
TEAOS 4 Years	2,637	2,255	2,118	2,720	2,337	2,049	2,463	2,927	2,603	3,448	2,916	2,508	30,981
TEAOS 5 Years	17	22	0	11	1	9	13	17	11	19	14	14	148
TEAOS 6+ Years	8	11	0	2	5	7	7	14	1	3	5	4	67
Total: Gains	2,716	2,318	2,164	2,794	2,413	2,107	2,518	2,992	2,636	3,502	2,963	2,550	31,673

Losses	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Attrition Losses	791	689	719	889	731	676	899	1,147	829	1,040	914	827	10,151
Physical	253	280	323	437	273	238	316	307	378	534	394	336	4,069
Hardship	17	32	12	9	24	23	20	32	12	14	9	13	217
Cause	408	296	278	351	327	329	441	419	302	394	348	274	4,167
Miscellaneous	113	81	106	92	107	86	122	389	137	98	163	204	1,698
EAOS Losses	1,268	967	880	1,335	1,197	971	1,159	1,240	1,205	1,757	1,274	1,114	14,367
Zone A : LOS <= 6 years	922	664	572	979	811	617	791	837	876	1,339	904	768	10,080
Zone B : LOS 7 to 10 years	242	213	218	258	291	250	291	307	253	307	293	264	3,187
Zone C : LOS 11 to 14 years	84	74	76	86	72	91	60	79	55	86	63	62	888
Zone D : LOS 15 to 20 years	20	15	14	10	22	13	17	17	20	23	14	18	203
Zone E : LOS >= 21 years	0	1	0	2	1	0	0	0	1	2	0	2	9
Retirement Losses	411	455	402	388	368	363	343	402	473	505	543	424	5,077
Trainee Losses	373	320	273	309	238	210	233	315	261	306	361	305	3,504
Total: Losses	2,843	2,431	2,274	2,921	2,534	2,220	2,634	3,104	2,768	3,608	3,092	2,670	33,099

Monthly Summary reports for single run output repeatability assessment for Experiment Two.

The scenarios were set up to run one iteration of the scenario and use fiscal year 2014 Manpower and Personnel data to project one year into the future (FY2015). All scenario inputs were kept at their default values and each scenario used the same 5 digit random seed (66389).

Monthly Summary Report for the First Scenario (seed 66389)

Start: FY15 - OCT   Number Of FYs: 1   Population Group: Active # Executions: 1
For sims that do not start in Oct, Report will use history for missing months data

Strength	Prev Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
Total with OCs	266,703	266,591	266,465	266,341	266,229	266,106	265,990	265,869	265,757	265,632	265,516	265,395	265,282	
Enlisted OCs	0	0	0	0	0	0	0	0	0	0	0	0	0	
Total without OCs	266,703	266,591	266,465	266,341	266,229	266,106	265,990	265,869	265,757	265,632	265,516	265,395	265,282	
WYA by Month	0	266,647	266,528	266,403	266,285	266,168	266,048	265,930	265,813	265,695	265,574	265,456	265,339	

Gains	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
PSG Gains	64	57	35	54	58	38	48	23	31	32	23	25	488
ADOS	0	0	0	0	0	0	0	0	0	0	0	0	0
Prior Service	41	32	13	27	29	12	17	6	11	3	3	3	197
Other Gains	23	25	22	27	29	26	31	17	20	29	20	22	291
NPS Gains	2,633	2,290	2,086	2,681	2,426	2,115	2,373	2,969	2,473	3,567	2,920	2,579	31,112
TEAOS 0 to 3 Years	0	0	5	0	0	0	1	0	0	0	1	0	7
TEAOS 4 Years	2,617	2,263	2,081	2,668	2,418	2,109	2,349	2,944	2,461	3,553	2,908	2,576	30,947
TEAOS 5 Years	9	18	0	10	3	6	6	13	10	14	9	3	101
TEAOS 6+ Years	7	9	0	3	5	0	17	12	2	0	2	0	57
Total: Gains	2,697	2,347	2,121	2,735	2,484	2,153	2,421	2,992	2,504	3,599	2,943	2,604	31,600

Losses	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Attrition Losses	803	691	719	936	744	721	856	1,173	830	1,058	800	863	10,194
Physical	249	277	306	458	267	251	307	319	391	508	391	379	4,103
Hardship	16	28	16	5	25	12	18	23	14	23	13	11	204
Cause	422	275	307	391	322	346	423	443	291	416	261	271	4,168
Miscellaneous	116	111	90	82	130	112	108	388	134	111	135	202	1,719
EAOS Losses	1,263	1,021	860	1,263	1,216	988	1,141	1,217	1,123	1,789	1,374	1,086	14,341
Zone A : LOS <= 6 years	927	683	570	900	820	670	776	797	784	1,326	984	748	9,985
Zone B : LOS 7 to 10 years	238	249	205	247	307	227	284	315	271	335	318	260	3,256
Zone C : LOS 11 to 14 years	78	70	70	103	66	80	64	82	56	96	55	63	883
Zone D : LOS 15 to 20 years	20	19	15	11	20	11	16	22	11	29	17	14	205
Zone E : LOS >= 21 years	0	0	0	2	3	0	1	1	1	3	0	1	12
Retirement Losses	411	454	402	387	365	361	322	420	451	543	533	456	5,105
Trainee Losses	332	307	264	261	282	199	223	294	225	325	357	312	3,381
Total: Losses	2,809	2,473	2,245	2,847	2,607	2,269	2,542	3,104	2,629	3,715	3,064	2,717	33,021

Monthly Summary Report for the Second Scenario (seed 66389)

Start: FY15 - OCT   Number Of FYs: 1   Population Group: Active # Executions: 1

For sims that do not start in Oct, Report will use history for missing months data

Strength	Prev Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Total with OCs	266,703	266,591	266,465	266,341	266,229	266,106	265,990	265,869	265,757	265,632	265,516	265,395	265,282
Enlisted OCs	0	0	0	0	0	0	0	0	0	0	0	0	0
Total without OCs	266,703	266,591	266,465	266,341	266,229	266,106	265,990	265,869	265,757	265,632	265,516	265,395	265,282
WYA by Month	0	266,647	266,528	266,403	266,285	266,168	266,048	265,930	265,813	265,695	265,574	265,456	265,339

Gains	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
PSG Gains	64	57	35	54	58	38	48	23	31	32	23	25	488
ADOS	0	0	0	0	0	0	0	0	0	0	0	0	0
Prior Service	41	32	13	27	29	12	17	6	11	3	3	3	197
Other Gains	23	25	22	27	29	26	31	17	20	29	20	22	291
NPS Gains	2,633	2,290	2,086	2,681	2,426	2,115	2,373	2,969	2,473	3,567	2,920	2,579	31,112
TEAOS 0 to 3 Years	0	0	5	0	0	0	1	0	0	0	1	0	7
TEAOS 4 Years	2,617	2,263	2,081	2,668	2,418	2,109	2,349	2,944	2,461	3,553	2,908	2,576	30,947
TEAOS 5 Years	9	18	0	10	3	6	6	13	10	14	9	3	101
TEAOS 6+ Years	7	9	0	3	5	0	17	12	2	0	2	0	57
Total: Gains	2,697	2,347	2,121	2,735	2,484	2,153	2,421	2,992	2,504	3,599	2,943	2,604	31,600

Losses	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Attrition Losses	803	691	719	936	744	721	856	1,173	830	1,058	800	863	10,194
Physical	249	277	306	458	267	251	307	319	391	508	391	379	4,103
Hardship	16	28	16	5	25	12	18	23	14	23	13	11	204
Cause	422	275	307	391	322	346	423	443	291	416	261	271	4,168
Miscellaneous	116	111	90	82	130	112	108	388	134	111	135	202	1,719
EAOS Losses	1,263	1,021	860	1,263	1,216	988	1,141	1,217	1,123	1,789	1,374	1,086	14,341
Zone A : LOS <= 6 years	927	683	570	900	820	670	776	797	784	1,326	984	748	9,985
Zone B : LOS 7 to 10 years	238	249	205	247	307	227	284	315	271	335	318	260	3,256
Zone C : LOS 11 to 14 years	78	70	70	103	66	80	64	82	56	96	55	63	883
Zone D : LOS 15 to 20 years	20	19	15	11	20	11	16	22	11	29	17	14	205
Zone E : LOS >= 21 years	0	0	0	2	3	0	1	1	1	3	0	1	12
Retirement Losses	411	454	402	387	365	361	322	420	451	543	533	456	5,105
Trainee Losses	332	307	264	261	282	199	223	294	225	325	357	312	3,381
Total: Losses	2,809	2,473	2,245	2,847	2,607	2,269	2,542	3,104	2,629	3,715	3,064	2,717	33,021

Monthly Summary reports for multiple run output repeatability assessment.

The scenarios were set up to simulate five iterations of the scenario and use fiscal year 2014 Manpower and Personnel data to project one year into the future (FY2015). All scenario inputs were kept at their default values and each scenario used the same five digit random seed (37295).

Monthly Summary Report for the First Scenario (seed 37295)

Start: FY15 - OCT   Number Of FYs: 1   Population Group: Active # Executions: 5
For sims that do not start in Oct, Report will use history for missing months data

Strength	Prev Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Total with OCs	266,703	266,583	266,463	266,348	266,228	266,108	265,990	265,871	265,748	265,635	265,517	265,397	265,278
Enlisted OCs	0	0	0	0	0	0	0	0	0	0	0	0	0
Total without OCs	266,703	266,583	266,463	266,348	266,228	266,108	265,990	265,871	265,748	265,635	265,517	265,397	265,278
WYA by Month	0	266,643	266,523	266,406	266,288	266,168	266,049	265,931	265,810	265,692	265,576	265,457	265,337

Gains	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
PSG Gains	62	39	39	67	55	48	47	37	21	35	26	24	500
ADOS	0	0	0	0	0	0	0	0	0	0	0	0	0
Prior Service	34	24	11	30	25	17	17	11	5	4	3	5	187
Other Gains	28	14	28	37	29	31	30	26	16	31	23	19	312
NPS Gains	2,616	2,322	2,108	2,672	2,417	2,071	2,435	2,877	2,562	3,437	2,916	2,528	30,963
TEAOS 0 to 3 Years	0	0	2	0	0	0	1	0	0	1	2	0	6
TEAOS 4 Years	2,596	2,292	2,106	2,661	2,402	2,064	2,414	2,842	2,542	3,419	2,906	2,512	30,757
TEAOS 5 Years	13	23	0	9	7	5	11	22	18	13	7	11	138
TEAOS 6+ Years	8	7	0	2	8	2	9	13	2	4	1	4	62
Total: Gains	2,678	2,361	2,147	2,739	2,472	2,120	2,482	2,914	2,583	3,472	2,942	2,551	31,462

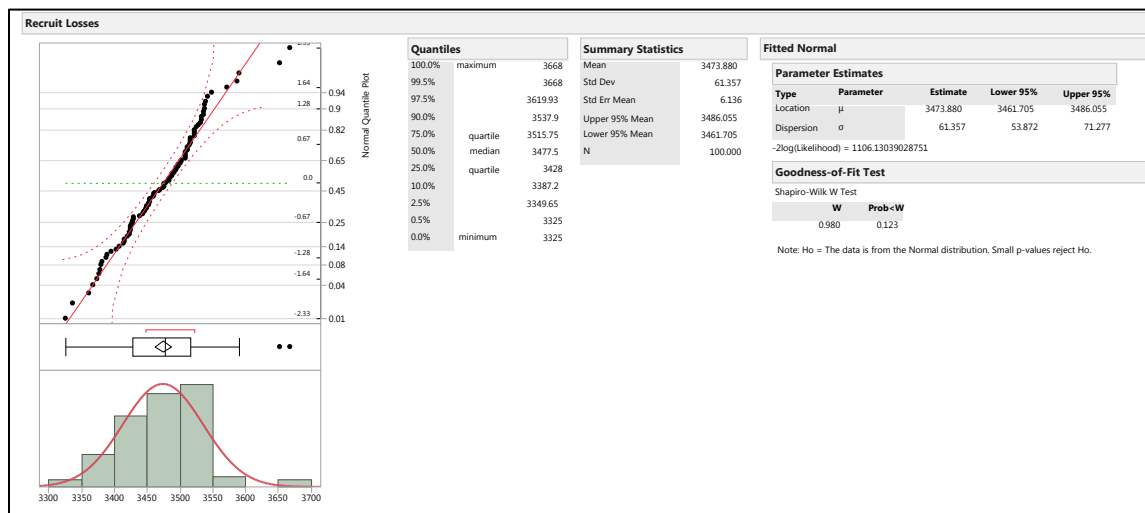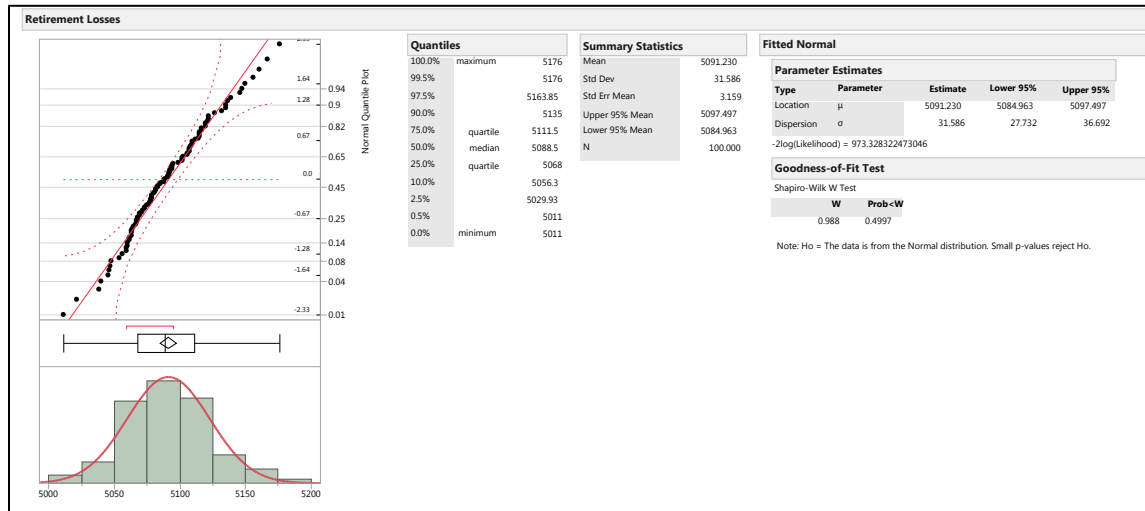| Losses	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Attrition Losses	772	683	711	908	738	710	869	1,148	831	1,032	829	825	10,055
Physical	259	248	296	441	294	243	306	287	371	507	379	348	3,979
Hardship	19	25	12	7	15	19	24	28	11	13	14	12	200
Cause	374	310	309	357	309	345	420	436	302	420	298	283	4,162
Miscellaneous	121	99	93	103	119	103	119	396	147	92	139	182	1,714
EAOS Losses	1,269	1,019	878	1,282	1,233	959	1,162	1,206	1,147	1,734	1,346	1,070	14,305
Zone A : LOS <= 6 years	920	684	584	939	820	645	796	799	816	1,307	929	720	9,959
Zone B : LOS 7 to 10 years	249	246	216	238	323	225	282	304	246	317	324	265	3,235
Zone C : LOS 11 to 14 years	81	70	63	88	72	74	62	86	70	87	77	63	893
Zone D : LOS 15 to 20 years	20	19	14	17	15	14	22	17	15	22	16	20	211
Zone E : LOS >= 21 years	0	0	0	1	3	1	0	0	0	1	0	1	8
Retirement Losses	411	455	401	387	365	363	342	399	468	502	524	471	5,087
Trainee Losses	346	325	272	283	255	205	228	285	250	322	363	304	3,440
Total: Losses	2,798	2,481	2,262	2,860	2,592	2,237	2,601	3,037	2,696	3,591	3,062	2,670	32,887

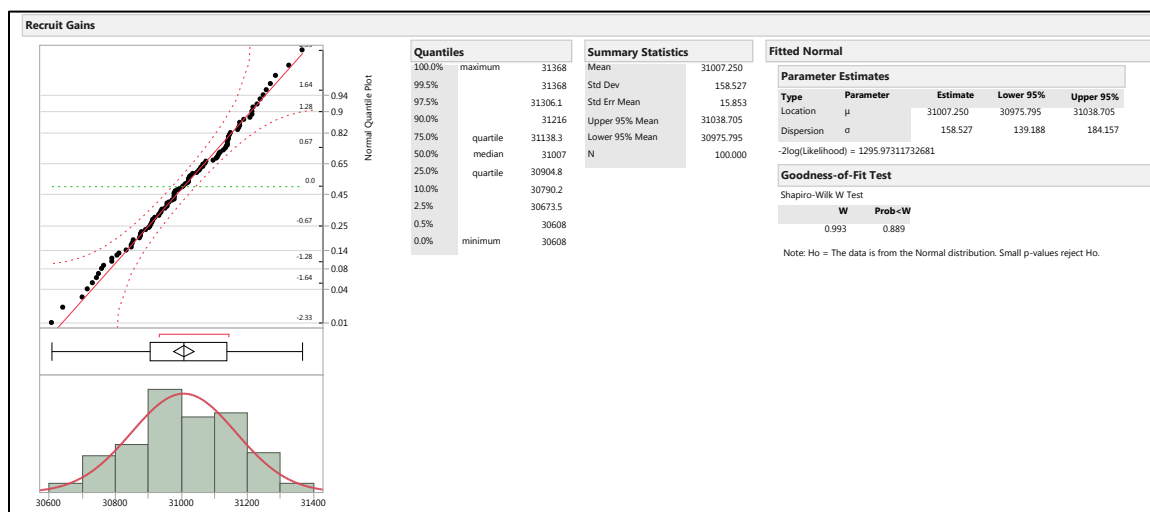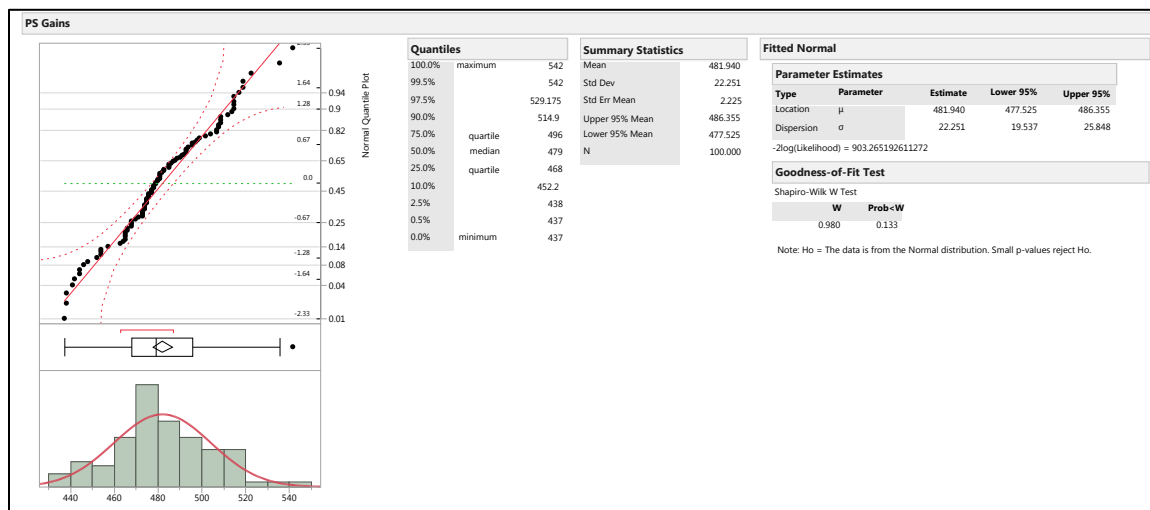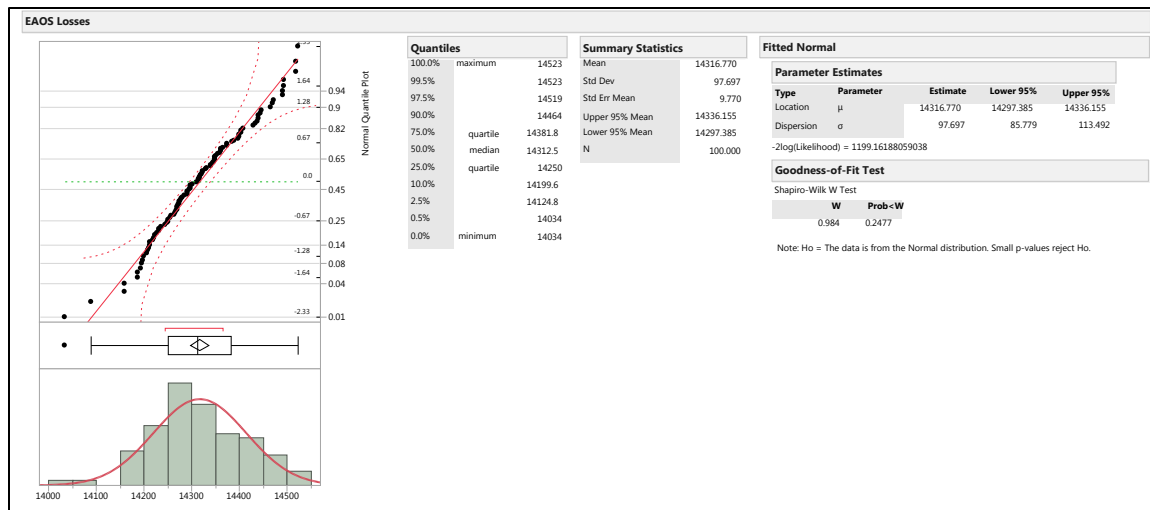## Monthly Summary Report for the Second Scenario (seed 37295)

Start: FY15 - OCT   Number Of FYs: 1   Population Group: Active   # Executions: 5

For sims that do not start in Oct, Report will use history for missing months data

Strength	Prev Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Total with OCs	266,703	266,583	266,463	266,348	266,228	266,108	265,990	265,871	265,748	265,635	265,517	265,397	265,278
Enlisted OCs	0	0	0	0	0	0	0	0	0	0	0	0	0
Total without OCs	266,703	266,583	266,463	266,348	266,228	266,108	265,990	265,871	265,748	265,635	265,517	265,397	265,278
WYA by Month	0	266,643	266,523	266,406	266,288	266,168	266,049	265,931	265,810	265,692	265,576	265,457	265,337

Gains	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
PSG Gains	62	39	39	67	55	48	47	37	21	35	26	24	500
ADOS	0	0	0	0	0	0	0	0	0	0	0	0	0
Prior Service	34	24	11	30	25	17	17	11	5	4	3	5	187
Other Gains	28	14	28	37	29	31	30	26	16	31	23	19	312
NPS Gains	2,616	2,322	2,108	2,672	2,417	2,071	2,435	2,877	2,562	3,437	2,916	2,528	30,963
TEAOS 0 to 3 Years	0	0	2	0	0	0	1	0	0	1	2	0	6
TEAOS 4 Years	2,596	2,292	2,106	2,661	2,402	2,064	2,414	2,842	2,542	3,419	2,906	2,512	30,757
TEAOS 5 Years	13	23	0	9	7	5	11	22	18	13	7	11	138
TEAOS 6+ Years	8	7	0	2	8	2	9	13	2	4	1	4	62
Total: Gains	2,678	2,361	2,147	2,739	2,472	2,120	2,482	2,914	2,583	3,472	2,942	2,551	31,462

Losses	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Attrition Losses	772	683	711	908	738	710	869	1,148	831	1,032	829	825	10,055
Physical	259	248	296	441	294	243	306	287	371	507	379	348	3,979
Hardship	19	25	12	7	15	19	24	28	11	13	14	12	200
Cause	374	310	309	357	309	345	420	436	302	420	298	283	4,162
Miscellaneous	121	99	93	103	119	103	119	396	147	92	139	182	1,714
EAOS Losses	1,269	1,019	878	1,282	1,233	959	1,162	1,206	1,147	1,734	1,346	1,070	14,305
Zone A : LOS <= 6 years	920	684	584	939	820	645	796	799	816	1,307	929	720	9,959
Zone B : LOS 7 to 10 years	249	246	216	238	323	225	282	304	246	317	324	265	3,235
Zone C : LOS 11 to 14 years	81	70	63	88	72	74	62	86	70	87	77	63	893
Zone D : LOS 15 to 20 years	20	19	14	17	15	14	22	17	15	22	16	20	211
Zone E : LOS >= 21 years	0	0	0	1	3	1	0	0	0	1	0	1	8
Retirement Losses	411	455	401	387	365	363	342	399	468	502	524	471	5,087
Trainee Losses	346	325	272	283	255	205	228	285	250	322	363	304	3,440
Total: Losses	2,798	2,481	2,262	2,860	2,592	2,237	2,601	3,037	2,696	3,591	3,062	2,670	32,887

APPENDIX C. A SUMMARY OF THE DISTRIBUTION OF RETIREMENT LOSSES, RECRUIT LOSSES, EAOS LOSSES, PRIOR SERVICE GAINS, AND RECRUIT GAINS

Retirement Losses

Quantiles

100.0%	maximum	5176
99.5%		5176
97.5%		5163.85
90.0%		5135
75.0%	quartile	5111.5
50.0%	median	5088.5
25.0%	quartile	5068
10.0%		5056.3
2.5%		5029.93
0.5%		5011
0.0%	minimum	5011

Summary Statistics

Mean	5091.230
Std Dev	31.586
Std Err Mean	3.159
Upper 95% Mean	5097.497
Lower 95% Mean	5084.963
N	100.000

Fitted Normal

Parameter Estimates

Type	Parameter	Estimate	Lower 95%	Upper 95%
Location	μ	5091.230	5084.963	5097.497
Dispersion	σ	31.586	27.732	36.692

-2log(Likelihood) = 973.328322473046

Goodness-of-Fit Test

Shapiro-Wilk W Test

W	Prob<W
0.988	0.4997

Note: Ho = The data is from the Normal distribution. Small p-values reject Ho.

Recruit Losses

Quantiles

100.0%	maximum	3668
99.5%		3668
97.5%		3619.93
90.0%		3537.9
75.0%	quartile	3515.75
50.0%	median	3477.5
25.0%	quartile	3428
10.0%		3387.2
2.5%		3349.65
0.5%		3325
0.0%	minimum	3325

Summary Statistics

Mean	3473.880
Std Dev	61.357
Std Err Mean	6.136
Upper 95% Mean	3486.055
Lower 95% Mean	3461.705
N	100.000

Fitted Normal

Parameter Estimates

Type	Parameter	Estimate	Lower 95%	Upper 95%
Location	μ	3473.880	3461.705	3486.055
Dispersion	σ	61.357	53.872	71.277

-2log(Likelihood) = 1106.13039028751

Goodness-of-Fit Test

Shapiro-Wilk W Test

W	Prob<W
0.980	0.123

Note: Ho = The data is from the Normal distribution. Small p-values reject Ho.

EAOS Losses

Quantiles

100.0%	maximum	14523
99.5%		14523
97.5%		14519
90.0%		14464
75.0%	quartile	14381.8
50.0%	median	14312.5
25.0%	quartile	14250
10.0%		14199.6
2.5%		14124.8
0.5%		14034
0.0%	minimum	14034

Summary Statistics

Mean	14316.770
Std Dev	97.697
Std Err Mean	9.770
Upper 95% Mean	14336.155
Lower 95% Mean	14297.385
N	100.000

Fitted Normal

Parameter Estimates

Type	Parameter	Estimate	Lower 95%	Upper 95%
Location	μ	14316.770	14297.385	14336.155
Dispersion	σ	97.697	85.779	113.492

-2log(Likelihood) = 1199.16188059038

Goodness-of-Fit Test

Shapiro-Wilk W Test

W	Prob<W
0.984	0.2477

Note: Ho = The data is from the Normal distribution. Small p-values reject Ho.

PS Gains

Quantiles

100.0%	maximum	542
99.5%		542
97.5%		529.175
90.0%		514.9
75.0%	quartile	496
50.0%	median	479
25.0%	quartile	468
10.0%		452.2
2.5%		438
0.5%		437
0.0%	minimum	437

Summary Statistics

Mean	481.940
Std Dev	22.251
Std Err Mean	2.225
Upper 95% Mean	486.355
Lower 95% Mean	477.525
N	100.000

Fitted Normal

Parameter Estimates

Type	Parameter	Estimate	Lower 95%	Upper 95%
Location	μ	481.940	477.525	486.355
Dispersion	σ	22.251	19.537	25.848

-2log(Likelihood) = 903.265192611272

Goodness-of-Fit Test

Shapiro-Wilk W Test

W	Prob<W
0.980	0.133

Note: Ho = The data is from the Normal distribution. Small p-values reject Ho.

Recruit Gains

Quantiles

100.0%	maximum	31368
99.5%		31368
97.5%		31306.1
90.0%		31216
75.0%	quartile	31138.3
50.0%	median	31007
25.0%	quartile	30904.8
10.0%		30790.2
2.5%		30673.5
0.5%		30608
0.0%	minimum	30608

Summary Statistics

Mean	31007.250
Std Dev	158.527
Std Err Mean	15.853
Upper 95% Mean	31038.705
Lower 95% Mean	30975.795
N	100.000

Fitted Normal

Parameter Estimates

Type	Parameter	Estimate	Lower 95%	Upper 95%
Location	μ	31007.250	30975.795	31038.705
Dispersion	σ	158.527	139.188	184.157

-2log(Likelihood) = 1295.97311732681

Goodness-of-Fit Test

Shapiro-Wilk W Test

W	Prob<W
0.993	0.889

Note: Ho = The data is from the Normal distribution. Small p-values reject Ho.

APPENDIX D. SUMMARIES OF REMANING META-MODELS

Retirement Losses

Summary of Fit

RSquare	0.9472
RSquare Adj	0.9397
Root Mean Square Error	11.162
Mean of Response	5077.4
Observations (or Sum Wgts)	17

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	5097.715	4.073	1251.7	<.0001*
Attrite U	2.117	0.147	14.37	<.0001*
Attrite U*Attrite U	-0.060	0.009	-6.69	<.0001*

Prior Service Gains

Summary of Fit

RSquare	0.8752
RSquare Adj	0.7781
Root Mean Square Error	1.374
Mean of Response	482.41
Observations (or Sum Wgts)	17

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	484.96	0.5189	934.67	<.0001*
Long Ext U	-0.196	0.0563	-3.49	0.0069*
Recruit P	-0.035	0.0184	-1.91	0.0889
Attrite U	0.0231	0.021	1.10	0.2989
Attrite P	-0.006	0.0201	-0.29	0.7775
Attrite U*Attrite P	0.0049	0.0011	4.48	0.0015*
Long Ext U*Long Ext U	-0.008	0.0012	-6.40	0.0001*
Long Ext U*Long Ext U*Long Ext U	0.0003	0.0001	3.31	0.0090*

Recruit Gains

Summary of Fit	
RSquare	0.9828
RSquare Adj	0.9788
Root Mean Square Error	2808.2
Mean of Response	36889
Observations (or Sum Wgts)	17

Parameter Estimates				
Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	29591	1025	28.88	<.0001*
Reenlist U	399.14	37.07	10.77	<.0001*
Attrite U	-857.3	37.07	-23.12	<.0001*
Attrite U*Attrite U	21.625	2.268	9.53	<.0001*

Recruit Losses

Summary of Fit	
RSquare	0.9883
RSquare Adj	0.9844
Root Mean Square Error	214.82
Mean of Response	3991.4
Observations (or Sum Wgts)	17

Parameter Estimates				
Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	3330	78.38	42.48	<.0001*
Reenlist U	34.89	2.836	12.30	<.0001*
Long Ext U	6.88	2.836	2.43	0.0320*
Attrite U	-76.7	2.836	-27.03	<.0001*
Attrite U*Attrite U	1.961	0.1735	11.30	<.0001*

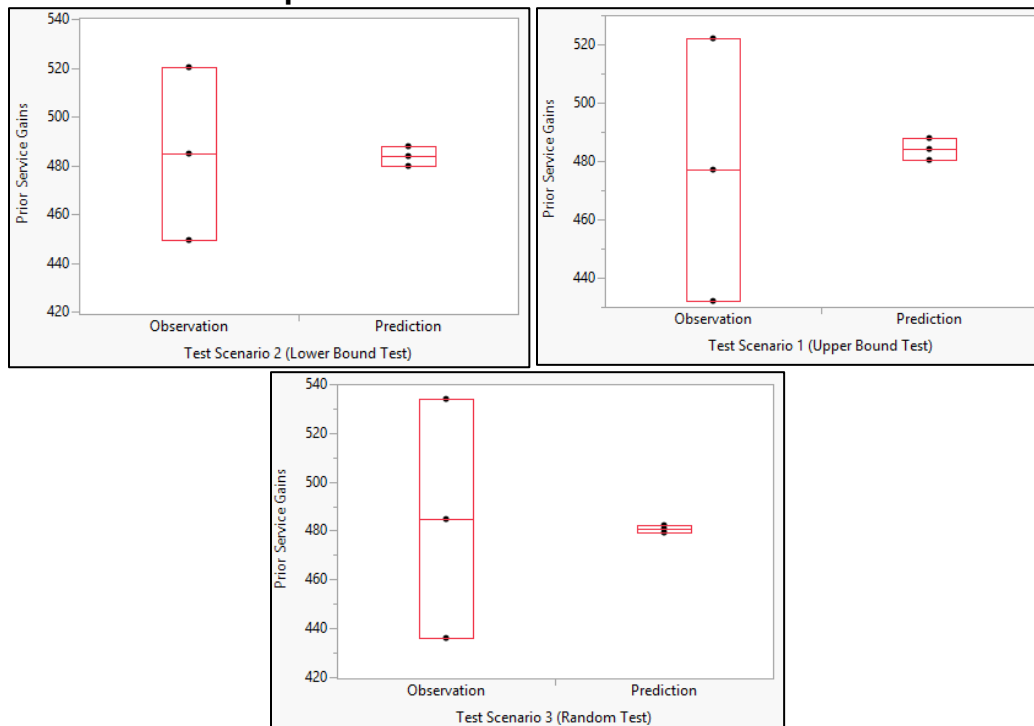# APPENDIX E. COMPARISON PLOTS FOR REMAINING META-MODELS

Comparison Plots for Retirement Losses

Test Scenario 1 (Upper Bound Test)

Test Scenario 2 (Lower Bound Test)

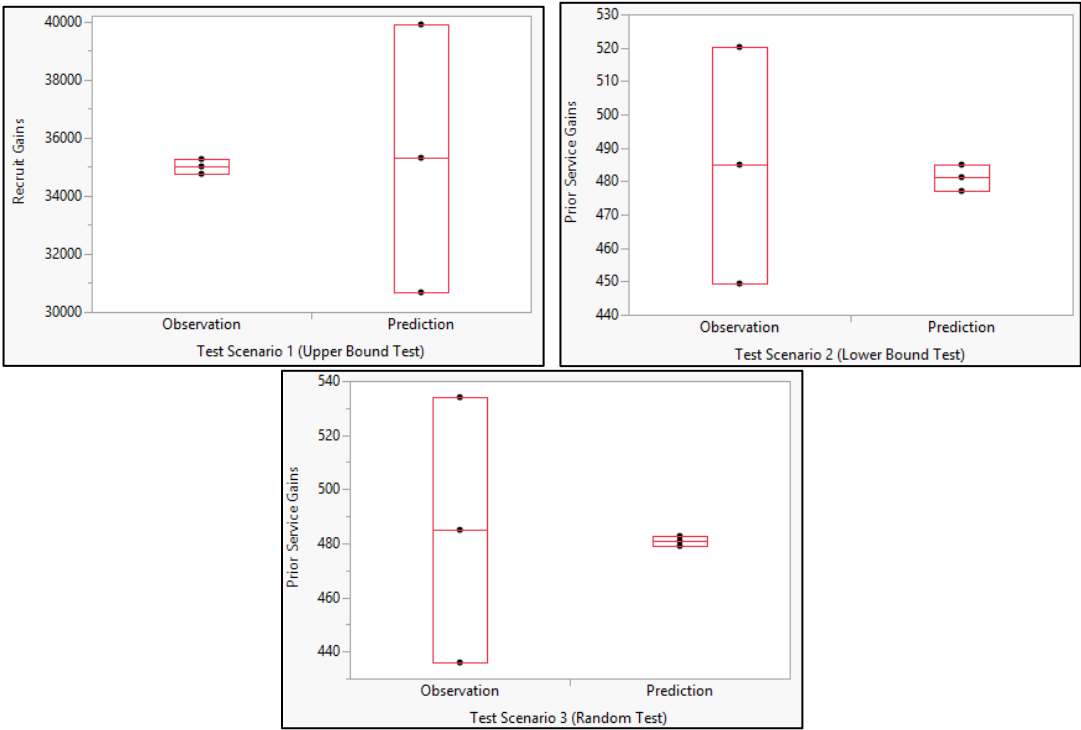Test Scenario 3 (Random Test)
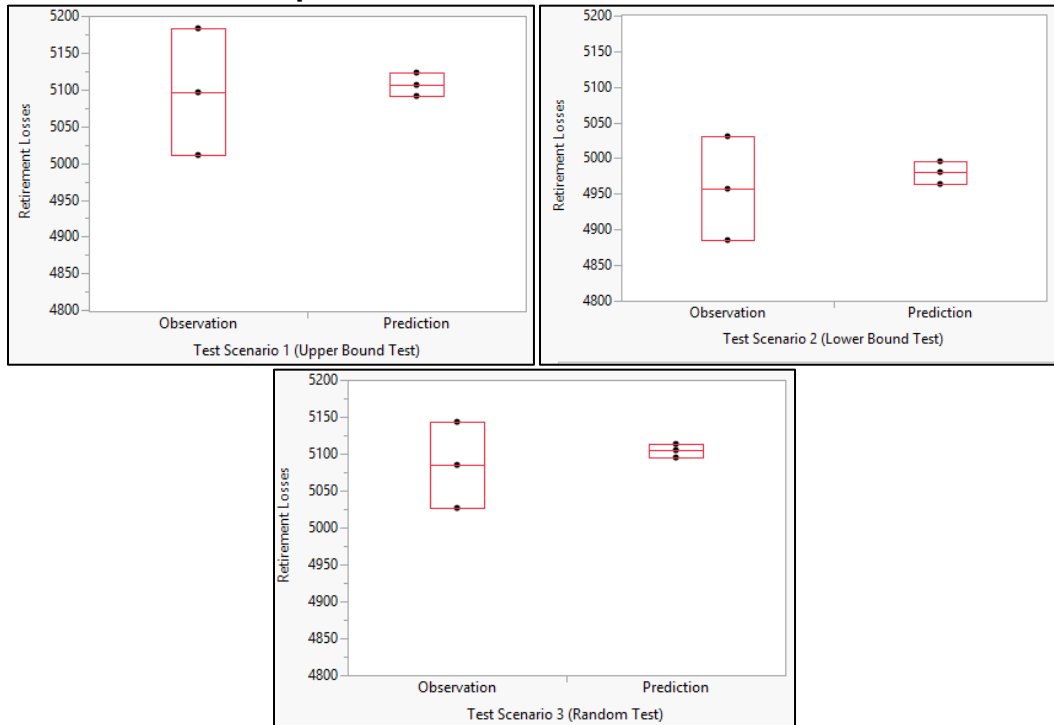
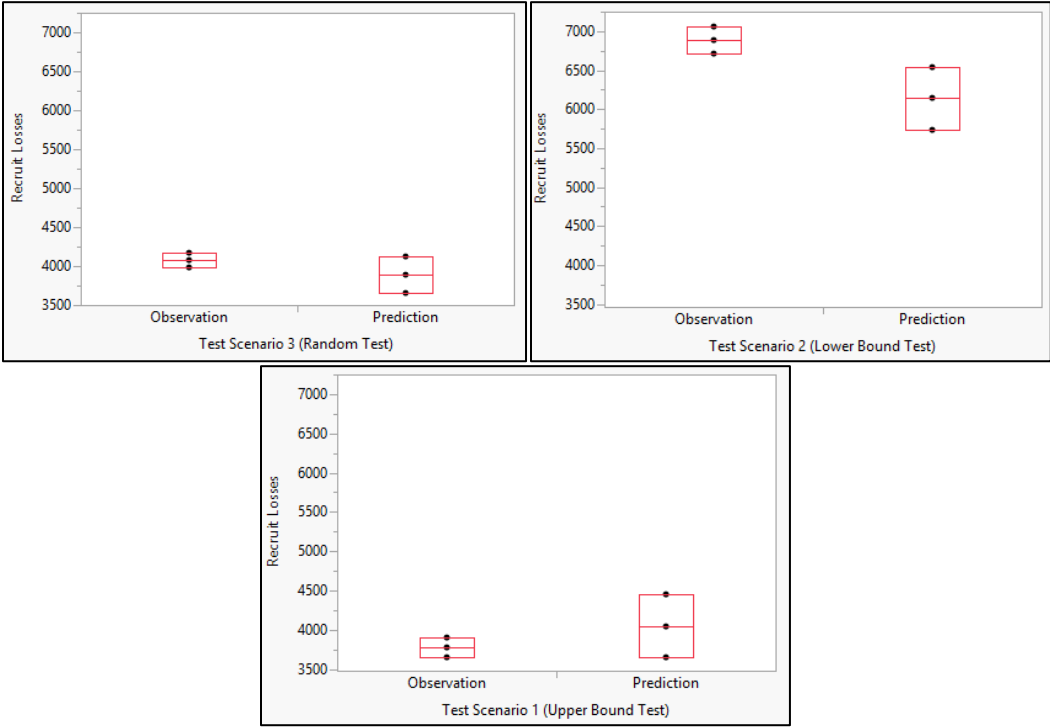# Comparison Plots for Attrition Losses
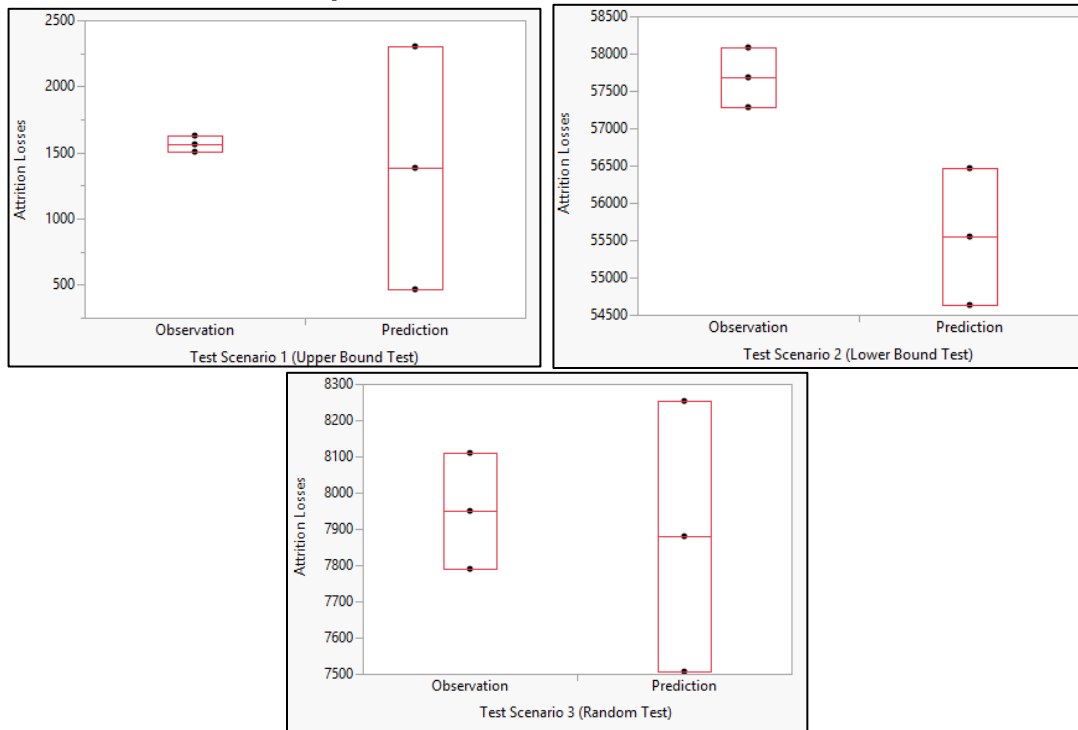
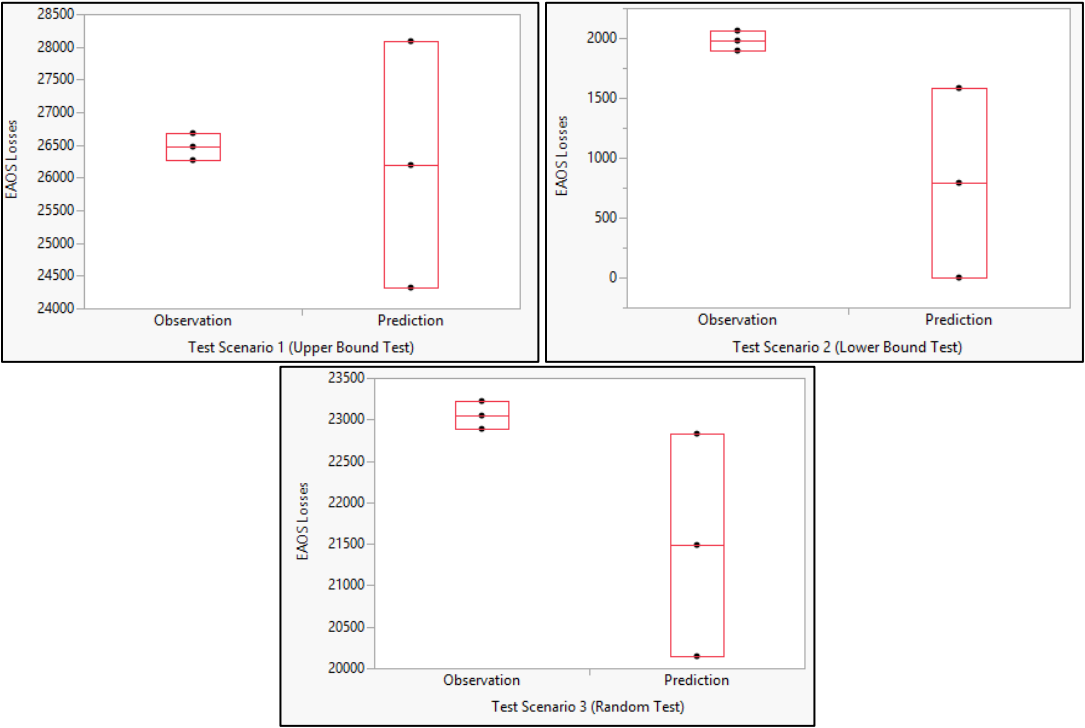# Comparison Plots for Prior Service Gains

Comparison Plots for Recruit Gains

Comparison Plots for Recruit Losses

71

Comparison Plots for EAOS Losses

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